Waste Management xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Waste Management

journal homepage: www.elsevier.com/locate/wasman

Content-based image retrieval system for solid waste bin level detection and performance evaluation

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ARTICLE INFO

Article history:
Received 21 October 2015
Revised 11 January 2016
Accepted 30 January 2016
Available online xxxx

Keywords:
CBIR
Feature extraction
Solid waste bin level
Gabor
GLCM
GLAM

ABSTRACT

This paper presents a CBIR system to investigate the use of image retrieval with an extracted texture from the image of a bin to detect the bin level. Various similarity distances like Euclidean, Bhattacharyya, Chi-squared, Cosine, and EMD are used with the CBIR system for calculating and comparing the distance between a query image and the images in a database to obtain the highest performance. In this study, the performance metrics is based on two quantitative evaluation criteria. The first one is the average retrieval rate based on the precision-recall graph and the second is the use of F1 measure which is the weighted harmonic mean of precision and recall. In case of feature extraction, texture is used as an image feature for bin level detection system. Various experiments are conducted with different features extraction techniques like Gabor wavelet filter, gray level co-occurrence matrix (GLCM), and gray level aura matrix (GLAM) to identify the level of the bin and its surrounding area. Intensive tests are conducted among 250 bin images to assess the accuracy of the proposed feature extraction techniques. The average retrieval rate is used to evaluate the performance of the retrieval system. The result shows that, the EMD distance achieved high accuracy and provides better performance than the other distances.

1. Introduction

Content-based image retrieval (CBIR) system is a process aims to search image databases for specific images that are similar to a given query image. The distance calculation between two image codes with equal length is the most common method for comparing two images (Ela et al., 2012). To develop an efficient CBIR system, significant features from each image in the database must be extracted to represent each image (Mascio et al., 2010). The similarity measurement between the query image and the images in the database is that the database must retrieve relevant images to the query. The distance metric can be used as the similarity measure, which is the key component in the CBIR system (Ciocca et al., 2011). Different similarity measurements should be investigated to obtain the best distance metric for the CBIR system.

In the CBIR system, different distance metrics between the query image and the images in the database are calculated; the result is ranked according to the minimum measure between the query image and the images in the database (Shrivastava and Tyagi, 2014). If the distance obtained is smaller, the query is probably more similar to the images in the database and is retrieved as required.

CBIR system is used to recognize and search vector images based on visual features (e.g., shape or color) instead of keywords or text annotations. The researchers had to solve the problems to satisfy the requirements of a 2D animation production environment. In 2D animation, experts have not found appropriate solutions for retrieving a customary shape-based image from the database and the CBIR system is simulated to overcome the problems. The CBIR system also deals with vector images through vector image search tool (VISTO) (Mascio et al., 2010). VISTO is a unique CBIR system for vector images and is designed to retrieve vector images in scalable vector graphics format. The approach entails transforming the image into an inertial system and using the center of mass as selected point descriptor vectors. The point vectors are built from moments of the inertial system, whereas the similarity between images is computed as the similarity of the associated description. The CBIR system is predominantly used for classification in many other applications such as medical

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http://dx.doi.org/10.1016/j.wasman.2016.01.046
0956-053X/

applications (Müller et al., 2004), biodiversity information systems (Davies and Bouldin, 1979; Torres et al., 2006) and digital libraries (Wang et al., 2004). Arebey et al. (2011) and other researchers have been developed an integrated SWM system to classify solid waste bin level (Hannan et al., 2011; Kemal et al., 2015). Various distances such as Euclidean, Bhattacharyya, Chisq, and Cosine were used with the five sets of bin images, which were classified as low, medium, full, flow, and overflow. The same database was used and the results from the two distances were compared to obtain the highest performance.

Feature extraction is an important phase of any classification system. Locating relevant and good features helps to lead high classification results. Different features are extracted depending on the problem's domain. For image classification, different features, such as structural features, statistical features, curvature features, projection profile, and gradient features were used in different studies. Many feature extraction techniques such as Gabor wavelets filter, gray level co-occurrence matrices (GLCM), gray level aura matrices (GLAM) are used for solid waste detection and classification purpose (Hannan et al., 2012, 2015). Gabor wavelets filter was applied to various image recognition problems for feature extraction due to its optimal localization properties in both spatial and frequency domain (Shafiqul et al., 2014). The Gabor wavelets were introduced to image analysis due to their biological relevance and computational properties (Jones and Palmer, 1987). The gray level co-occurrence matrices (GLCM) provide a second-order method for generating texture features (Haralick et al., 1973; Tien et al., 2008). GLCM calculates the relationship between the conditional joint probabilities of all pair wise combinations of gray levels in the image given the two parameters, such as displacement and orientation (Liu and Yang, 2008). The GLCM is calculated as symmetric or non-symmetric matrices (Honeycutt and Plotnick, 2008). The concept of gray level aura matrix (GLAM) is to form image X as a finite rectangular lattice S of $m \times n$ grids with a neighborhood system N_s (Xuejie and Yee-Hong, 2007). The N_s at site s can be viewed as the translation of a basic neighborhood structuring element for the neighborhood system N (Xuejie and Yee-Hong, 2007). Aura set deals with A as one set and calculates the neighbors of A with B. The aura calculates the neighbor of each element A with B.

There have several systems that used smart bin to monitor the solid waste content inside a trash bin (Al Mamun et al., 2013, 2015, 2016; Folianto et al., 2015; Hannan et al., 2012; Islam et al., 2014; Rada et al., 2013). Different kinds of sensing, data acquisition and communication technologies have been employed to develop a smart bin that make a system complicated and costly. On the other hand, the use of image processing techniques for solid waste bin level detection facilitates for real-time monitoring of trash bin. A CBIR system provides the opportunity to investigate the use of image retrieval with the extracted features of the image and classify them accordingly to acquire the bin fill level. Thus, CBIR is a good choice for the waste solid bin level detection.

The main objective of the paper is to deal with content-based image retrieval (CBIR) system for solid waste bin level detection and performance evaluation. Different distances were used with the five sets of bin level to develop the database of the CBIR system. Various experiments were conducted with different features extraction techniques to identify the level of the bin and its surrounding area for the bin level detection system. The performance comparison between the distances and feature extraction techniques provide the best choice bin level detection system. With the developed system, the information of solid waste during the collection could be updated in real time and keeps the information in the system database which starts from waste generation to its final destination.

2. Content-based image retrieval system

Content-based image retrieval system (CBIR) is proposed to identify the solid waste bin level. CBIR aims at searching databases for specific images that are similar to a given query. In comparing two bin images, the most common method is to calculate the distance between two equal length image codes (Lim, 2001). The CBIR mainly consists of the distance metric used to measure the similarity between images and the evaluation of similarity measurements, which are explained in more detail below.

2.1. CBIR structure

The proposed CBIR system aims to investigate the use of image retrieval with an extracted texture from the image of the bin to detect the bin level. Fig. 1 shows the CBIR system architecture for image indexing and query image retrieval from the database. Various similarity distances are proposed to be used with the CBIR system. The developed CBIR system has two issues: (i) significant features from each image in the database must be extracted to represent each image efficiently and (ii) similarity measurement between the query image and the images in the database must retrieve relevant images for the query.

To identify the bin level, it is necessary to obtain reliable image data, as well as the quality and quantity of these images. The purpose of taking the bin images at different levels is to create a robust image database to be used with the intelligent classification technique, or to compare the query image with the robust database in the retrieval technique such as CBIR. The captured image is stored into a related database and a request is sent to the server to upload the image. All real-time information on the solid waste bin and GPS data are forwarded to the server through the GPRS modem with the availability of the GPRS network. Detail of the database construction process and its challenges are explained in Arebey et al. (2011) and Hannan et al. (2011). Different image processing techniques are applied on the received images to estimate the level of bin.

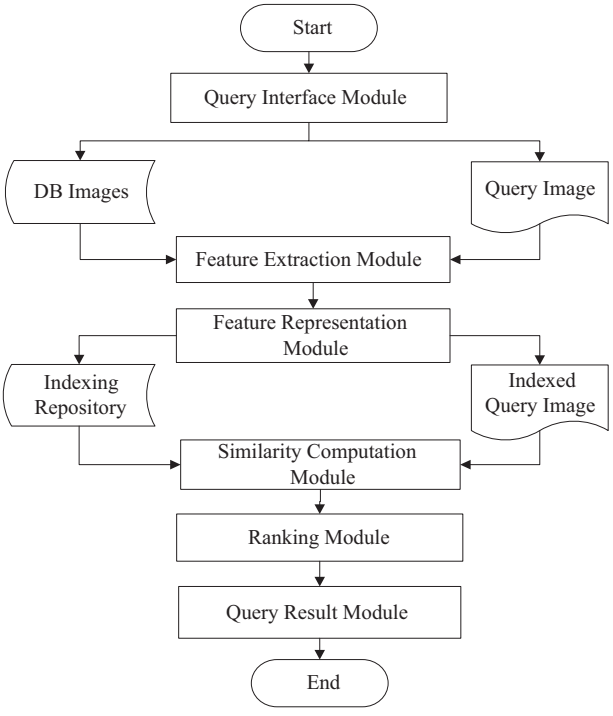

Fig. 1. Architecture of content based image retrieval system.

Please cite this article in press as: Hannan, M.A., et al. Content-based image retrieval system for solid waste bin level detection and performance evaluation. Waste Management (2016), http://dx.doi.org/10.1016/j.wasman.2016.01.046