Expert Systems With Applications 48 (2016) 76–88

Contents lists available at ScienceDirect

Expert Systems With Applications

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

Theoretical model and implementation of a real time intelligent bin status monitoring system using rule based decision algorithms

Md. Abdulla Al Mamun[a,*], M A Hannan[a], Aini Hussain[a], Hassan Basri[b]

[a] Department of Electrical, Electronic and Systems Engineering, Faculty of Engineering & Built Environment, Universiti Kebangsaan Malaysia, Bangi, Selangor DE, Malaysia

[b] Department of Civil and Structural Engineering, Faculty of Engineering & Built Environment, Universiti Kebangsaan Malaysia, Bangi, Selangor DE, Malaysia

ARTICLE INFO

Keywords:
Solid waste
Smart bin
Decision algorithm
Wireless sensor network
ZigBee

ABSTRACT

Due to the rising trend of urbanization along with overconsumption of non-recyclable resources, the volume of municipal solid waste is increasing every day. An efficient, cost effective and environment friendly solution for real time bin status monitoring, collection and transportation of municipal solid waste is still a major challenge to the local municipal authorities. This research proposes a novel model, architecture and intelligent sensing algorithm for real time solid waste bin monitoring system that would contribute to the solid waste collection optimization. The monitoring application is based on decision algorithms for sensing solid waste data in a wireless sensor network. The system is built on a three level architecture like smart bin, gateway and control station. The elementary concept is that, smart bins collect their status when any changes occur and transmit the status data to a server via an intermediate coordinator. A set of applications in server presents the updated bin status on real time. The field test performances show that the system can efficiently monitor real time bin status that makes it feasible to decide, which bin should collect and which should not. Thus the proposed system has achieved its goal to provide real time bin status information to the solid waste management operator. Later, this information can be used for collection route optimization to reduce collection costs and carbon emissions which in turn contribute to build green society.

© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

The term Municipal Solid Waste (MSW), also named as garbage or trash, generally comprises of daily stuffs that we used and then thrown away. These stuffs include food scraps product packaging, newspapers, clothing, grass clippings, bottles, furniture, batteries, paint, appliances etc. that comes from our households, institutes, markets, hospitals, and trades etc. (Municipal Solid Waste, 2012). Due to the overconsumption of non-renewable resources, the volumes of MSW are increasing day by day. The generation as well as the recycling, composting, and disposal of MSW have changed substantially over the last few decades. In urban areas the waste generation rate is about 760,000 tons on daily basis and is anticipated to rise about 1.8 million tons per day by the year 2025 (World Bank, 1999).

At present, the issues of waste collection and transport and its impact to human health due to pollutant emissions, noise, traffic, and so on is of big concern. The increasing numbers and unplanned usage of waste collection vehicles consumes a lot of fuel that turn in salient contribution to gassy pollutant and greenhouse gas (GhG) emissions, mainly in city areas. The bins that are partially fill up when collecting seems an unnecessary wastage of resources. By optimizing the number of bin, location of the bin and frequency of their collection is an important way to reduce the cost and emission in solid waste collection (Badran & El-Haggar, 2006; Chang & Wei, 1999; Faccio, Persona, & Zanin, 2011; Johansson, 2006; Kulcar, 1996; Lin, Chen, Lee, & Lin, 2010). A waste collection truck with diesel engine emits an average of 2.4 kg/km for CO_2, 0.21 g/km for HC, 7.4 g/km for CO, 32.3 g/km for NO_x and 46.4 mg/km for *Particular Matter*. And this data for a truck with CNG engine is 3.6 kg/km for CO_2, 2.19 g/km for HC, 15.8 g/km for CO, 4.38 g/km for NO_x and 11.4 mg/km for *Particular Matter* (Fontaras et al., 2012). One reckoning presented that 5.87 L of fuel is consumed for every ton of waste collection which emits 4.40 kg CE of GHG (Chen & Lin, 2008). Again, it is very expensive for the municipality to collect, transfer and transport solid waste. These operations constitute about 80–95% of the whole budget for solid waste management; so it figures the key element in ascertaining the finances of the entire waste management process (Alagöz & Kocasoy, 2008).

Over the past few years, wireless sensor networks (WSN) have been deployed in various applications especially in case of remote monitoring, aiming to eliminate the web of wires as well as to reduce cost while extending network coverage. In the last decade, a

* Corresponding author. Tel.: +880-1718890345.
E-mail addresses: md.abdulla@siswa.ukm.edu.my, mamun@hstu.ac.bd, mamuncse_hstu@yahoo.com (Md.A.A. Mamun), hannan@ukm.edu.my (M.A. Hannan), aini@eng.ukm.my (A. Hussain), drhb@ukm.my (H. Basri).

http://dx.doi.org/10.1016/j.eswa.2015.11.025
0957-4174/© 2015 Elsevier Ltd. All rights reserved.

huge number of applications like habitat monitoring, building automation, smart energy, health care, water and air quality monitoring, construction health monitoring, agriculture and food industry, fire detection that had been developed in adopting ZigBee and GSM technology (Fraile, Bajo, Corchado, & Abraham, 2010; Han & Lim, 2010; Khedo, Perseedoss, & Mungur, 2010; Kistler, Bieri, Wettstein, & Klapproth, 2009; Mainwaring, Culler, Polastre, Szewczyk, & Anderson, 2002; Wang, Zhang, & Wang, 2006; Yu, Wang, & Meng, 2005). Now it is more awaited that WSN with currently developed more advance communication technologies leads to solve various problems towards building smart world and also brings significant benefits in reducing cost. The aim of this work is to design a frame work for collecting bin status data in real time that can help to optimize waste collection route by using the collected data to reduce operation costs and GhG emissions as well.

2. Related works

In 1961, Solleftea hospital in Sweden installed the world's first ever automatic refuse collection system named Centralsug (current Envac) which was pneumatic and then in 1965, the residential district of Or-Hallonbergen installed the first vacuum system for household waste management (Vacuum system history, n.d.). Still today, these systems are performing operations using the basic functions and structures from the early 1960 s. From that time, many researchers give contributions in the field of waste management, waste monitoring, incineration management, waste to energy conversion, and land filling (Arebey, Hannan, Begum, & Basri, 2012; Chen & Li, 2010; Hannan, Arebey, Begum, & Basri, 2011). Many researches have been undertaken to design and develop a system that can monitor and manage the solid waste collection process. (Cheng, Chan, & Huang, 2003; Lei, Chuanhua, Yuezhao, Haijun, & Yanghuiqin, 2011; Noche, Rhoma, Chinakupt, & Jawale, 2010). However, very little of research is done in the field of solid waste bin monitoring, specifically, on real time monitoring.

An initiative was taken by the Swedish producers association, which equipped 3300 bins around the country with sensors and wireless communication equipment in order to estimate the bin fill level (Johansson, 2006). Each bin contains four infrared LED and a tilt sensor, mounted under the bin cover. The sensing system is activated once every hour and measures the fill level of the container. If three out of the four infrared beams are broken, the system is triggered and sent an alarm along with an email to the operator via GSM. A second alarm is sent in the same way when all the four beams are broken. It also sent a reset signal after the bin has been emptied (Johansson, 2006). The strengths of the system are that it can estimate bin fill level and facilitates to implement route optimization with low operation cost. The weaknesses of the system are the inability to measure exact fill level and weight along with delayed system responses.

One research have been conducted to develop bin status monitoring system for the municipality of Pudong (Shanghai), by combining camera with others ICTs that can measure bin fill level as well as weight of waste inside bin in real time (Rovetta et al., 2009; Vicentini et al., 2009). As described by the authors, a camera is attached with a set of sensors such as ultrasonic, LEDs on the top of the bin, which enables it to collect information about the shape, area and height of the waste. The LEDs provide illumination to enable more accurate volume estimation. The bottom of the bin is equipped with a sensor which constantly scales the weight of the waste. GPRS module is installed with the bin to transmit acquired data to the control station. The functionalities of the system is that, bin status monitoring mainly focus on early gathering of data about the waste in the bins and secondly, the transmission of the information to the operation center software which maps, monitors and plans for route optimization with the help of GPS and GIS. The strengths of these studies are the enhancement of the bins with a variety of sensors and cameras. However, the designed systems does not support a wireless sensor network for further fusion of the sensor data neither supports RFIDs for bin tagging and identification and GPRS in every bins increase the operation costs. Also the camera produces low quality images and estimates the level of the bin wrongly if the bin is dirty and position of the camera affects the system performance (Islam et al., 2014).

Another system has been developed for bin status monitoring using various ICTs such volumetric sensor, RFID, weighing system, GPRS and GPS (Faccio et al., 2011). The system is designed with RFID tag at the bin level for identification; the RFID reader attached on the vehicle's bin hook to keep the scanning distance below 1 m; a programmable microprocessor is installed inside the bin to manage the detection measures of fill level using a volumetric ultrasonic detection sensor; weighing system in the vehicle; GPRS module in the bins, vehicles and control center; and software applications in vehicle and control center to trace next bins to be served and to collect and analyze data accordingly. The strengths of the system are that it can estimate bin fill level and facilitates to implement route optimization with real time system responses. But the developed system has a high operation cost as every bin contain GPRS module and it is unable to measure weight.

Arebey, Hannan, Basri, Begum, and Abdullah (2011); Arebey et al. (2012); Arebey, Hannan, and Basri (2013) and Hannan et al. (2011) studied that, the integration of a number of ICTs can estimate the quantity of waste as well as monitor trash bins and collection vehicles. They have developed a bin monitoring system with RFID, camera, GPS, GIS and GPRS. The system starts its operation with the driver being assigned with a specific vehicle and a specific route. The driver turns on the black box controller installed in the vehicle, which activates the RFID reader, the camera, the GPS and the GSM/GPRS modules in order to prepare the vehicle for transmitting information to a control station. The system is based on the wireless communication between the bins and vehicles, and between the vehicle and the control station. When the vehicle approaches the bin area, the RFID reader identifies the bin tag and the camera snaps two pictures before and after the collection to estimate the amount of waste. According to the authors, it is important to highlight that the collection operators are responsible for the adjustment of the camera to find the best direction for taking a proper image of the bin and its surroundings. Moreover, they need to open the lid for capturing the two images. The fill level of a bin is estimated based on a comparison of the images by using some image analysis procedures at the server. The strengths of the paper are the intelligent system incorporated for bins and trucks monitoring as well as the enhanced communication technologies. However, the model exploits data produced only from a specific type of data acquisition device and not considers real time bin information. Also the system has performance problems due to the placement of camera during bin status data collection.

In Muthukumaran and Sarkar (2013) the authors have proposed a solid waste disposal system using mobile adhoc networks. The paper presents a model for waste collection of bins, distributed in a highly densely populated city in India. It is formed a dynamic multi-hop network that can provide real time information to municipal authorities. The system is able to monitor online and visualize the status of the bins for further use; due to a capacity sensor and adhoc transceivers embedded in the bins. The strengths of the paper are the incorporation of a dynamic multi-hop network along with the online monitoring and visualization utilities. However, the paper does not use a variety of sensors since the data produced only from a specific type of capacity sensor.

In McLeod et al. (2014) the authors have proposed a model for remote monitoring of charity assets in order to improve collection efficiency. It is proposed a model from a major UK charity, in order to monitor bank and shop servicing requirements. The system incorporates sensors embedded into bins and uses tabu search methods; to develop dynamic scheduling and routing models for waste

Download English Version:

https://daneshyari.com/en/article/384091

Download Persian Version:

https://daneshyari.com/article/384091

Daneshyari.com