Mobile Green E-Waste Management Systems using IoT for Smart Campus

K. N. A. Rani1,2*, H. A. Rahim1,2, B. T. Ong2, M. Jusoh1,2, M. N. M. Yasin1,2, T. Sabapathy1,2, W. A. Mustafa3, M. A. Jamlos1,2, R. B. Ahmad2, D. A. Hammood4

1 Advanced Communication Engineering, Centre of Excellence (ACE), Universiti Malaysia Perlis (UniMAP), 01000 Kangar, Perlis, MALAYSIA
2 Faculty of Electronic Engineering Technology (FTKEN), Universiti Malaysia Perlis (UniMAP), 02600 Arau, Perlis, MALAYSIA
3 Faculty of Electrical Engineering Technology (FTKE), Universiti Malaysia Perlis (UniMAP), 02600 Arau, Perlis, MALAYSIA
4 Electrical Engineering Technical College/ Middle Technical University (MTU) Al Doura, 10022, Baghdad, IRAQ

*Corresponding author: khairulnajmy@unimap.edu.my

Abstract. This paper presents the design and development of mobile “green” electronic waste (e-waste) management systems using Internet of Things (IoT) for smart campus. The system uses Raspberry Pi 3 Model B v1.2 microcontroller for monitoring e-waste object detection, e-waste count, and bin percentage level, respectively. TensorFlow Lite application programming interface (API) is used to run Single Shot Multibox Detector (SSD)Lite-MobileNet-v2 model trained on Microsoft Common Objects in Context (MSCOCO) dataset for e-waste object detection in image. All the monitoring data are stored and retrieved in ThingSpeak cloud platform using Hypertext Transfer Protocol (HTTP) and Message Queuing Telemetry Transport (MQTT) protocol over the Internet and displayed via interactive Android-based mobile user interface (UI). Furthermore, automatic e-mail notification will be sent to waste collector for bin collection whenever e-waste bin percentage level is greater than predetermined threshold value of 80% full.

Keywords: Electronic Waste, Internet of Things, Object Detection Model, Android User Interface, Smart Campus, Wearable Device

1. Introduction

Smart campus is defined as places where the devices and applications create new experiences or services and facilitate operational efficiency same concept as smart city. In other words, smart campus is an emerging trend that allows educational institutions to combine smart technologies with physical infrastructure for improved services, decision making, and campus sustainability [1]. Internet of Things (IoT) become as one of the most powerful communication technologies of the 21st century where most of consumer electronic devices are part of the Internet due to its communication and computing abilities.
[2]. IoT-based solutions are considered the backbone of any smart infrastructure [3] and future embedded computing structure [4]. Such smart solutions efficiently mobilize and use the needed resources for improving the quality of life of residents, decreasing pressure on the environment, encouraging innovation, and fostering a well-developed local community. Moreover, smart solutions are applicable for real-time visual monitoring of objects within a specific environment using sensors [5], wearable devices [6]-[8] monitoring system, and radio frequency (RF) energy harvesting system [9]-[11]. The integration of IoT and smart phones has revolutionized industry where more and more solutions are being developed aiming user convenience. Amazon's Alexa, Apple's Siri, and Google's Assistant are a few examples that facilitate the smart living with great comfort and ease. Nowadays, the smart campuses may grow faster than the smart cities as the cutting-edge technologies have entered to this era globalization, such as IoT, artificial intelligence (AI), and big data analytics. Inspired from the smart city concepts, smart campus is an emerging trend that make efficient uses of infrastructure. Fig. 1 shows the smart campus and its conceptual components where waste management is one of the components.

Electronic waste (e-waste) basically refers to discarded electrical or electronic devices. Used electronic components, which are meant for refurbishment, reuse, resale, salvage recycling through material recovery, or disposal are also considered e-waste. Mishandling of recycling and dumping of e-waste scrap parts can harm human health and pollute environment. Some of e-waste leftovers contain toxic materials, such as lead, cadmium, beryllium, and brominated flame retardants. It is reported e-waste has become “fastest-growing waste stream in the world” with 44.7 million tons generated in 2016 equivalent to 4500 Eiffel towers [12]. In 2018, an estimated 50 million tons of e-waste was reported, thus the name “tsunami of e-waste” given by the United Nation (UN) with the value of at least $62.5 billion annually [13]. Some studies were done in developing e-waste bin. In [14], e-waste bin with the shortest path algorithm for identifying bin was developed but it did not have object detection. [15] proposed e-waste bin with route optimization system of collection routes for vehicle fleet but also had no object detection. Lastly, authors in [16] designed e-waste bin with Global System for Mobile Communications (GSM) module to establish communications with mobile device or bin but there were no ultrasonic and infrared (IR) sensors used.

This paper presents mobile e-waste management system, which is environmental-friendly or “green” and more convenient designed and developed by Universiti Malaysia Perlis (UniMAP). This proposed system deploys IoT applications to relieve the constant needs of manpower. This can reduce highly risk hazardous effects on health and environment due to improper disposal of mobile e-waste.
2. System Structure and Design

2.1. System Architecture

Fig. 2 illustrates the system architecture for this project. The system begins with e-waste object image captured using five megapixels (5 MP) Pi camera located above bin, which includes discarded central processing unit (CPU) motherboard, smartphone, microcontroller, batteries, and electronic components. The e-waste image will become as input data for TensorFlow Lite application programming interface (API) to run Single Shot Multibox Detector (SSD)Lite-MobileNet-v2 object detection model trained on Microsoft Common Objects in Context (MSCOCO) dataset. Infrared (IR) sensor is used to count e-waste object being dumped whereas ultrasonic sensor is used to calculate the percentage level of bin being filled up by e-waste (based on the distance between e-waste and bin cover). Raspberry Pi 3 Model B v1.2 microcontroller board controls Pi camera as well as both IR and ultrasonic sensors in this system. All the monitoring e-waste object detection, count, and bin percentage level data are stored and retrieved in ThingSpeak cloud platform using Hypertext Transfer Protocol (HTTP) and Message Queuing Telemetry Transport (MQTT) protocol over the Internet. The data can be accessed and displayed using interactive Android-based mobile user interface (UI). The system also will send automatic e-mail notification via Secure Simple Mail Transfer Protocol (SSMTP) to waste collector for bin collection whenever e-waste bin percentage level saved in ThingSpeak cloud server is greater than predetermined threshold value of 80% full. Moreover, the e-waste collector can know condition and track location of bin from website.
Fig. 2. System Architecture
Fig. 3(a). Overall System Flowchart (Part A)
Fig. 3(b). Overall System Flowchart (Part B)
Fig. 3(a) and 3(b) show the flowchart of the proposed green e-waste management system for smart campus. It covers all the operations of the system starting from e-waste object detection till alert e-mail notification with predefined conditions.

3. Result and Discussion

Fig. 4 shows e-waste bin prototype with dimension of 100 cm × 40 cm × 40 cm. Fig. 5 shows the interfacing of Raspberry Pi 3 microcontroller board with Pi camera for object detection. Fig. 6 shows ultrasonic sensor, infrared sensor and servo motor are attached unto cover of e-waste bin. The servo motor is primarily used to open and close e-waste bin cover automatically.
Fig. 5. Top View of Prototype

Fig. 6. Sensor and Servo inside Bin

Fig. 7 shows keyboard is detected with the learning rate of 67% based on quantized SSDLite-MobileNet-v2 object detection model trained and run by TensorFlow Lite API. Moreover, mobile phone is detected at the rate of 65%, laptop is detected at the rate of 58%, television is detected at the rate of 58%, mouse is detected at the rate of 57%, and remote control is detected at the rate 73%, respectively. Fig. 8 shows the e-waste count is incremented as detected e-waste scrap dropped into bin.
Fig. 7. Detection Result on Keyboard

Fig. 8. Data Result in Thonny Python IDE

Fig. 9 shows e-mail notification is delivered for bin collection as bin percentage level reaches 80% full. Fig. 10 shows some part of the important information related to mobile e-waste and related statistics. These information serves to educate users on mobile e-waste recycling.
Fig. 9. Alert e-Mail Notification

Fig. 10. Homepage Website on e-Waste Management System

Fig. 11 shows website on location of bin officially launched by Malaysian Communications and Multimedia Commission (MCMC). Fig. 12 shows the website on condition of bin that can only be accessed by registered and authorized users.
4. Conclusion

In sum, the e-waste bin prototype in this project is successfully developed and can fulfill any beneficiary with high awareness of e-waste recycling. It is proven that this green e-waste management system operates smoothly in detecting electronic scraps dropped by user properly in e-waste bin in UniMAP. It also integrates some features to help authorities to monitor status of e-waste bin percentage level, e-waste object detection, and e-waste count, respectively. All the data status are stored and retrieved in ThingSpeak cloud platform using Hypertext Transfer Protocol (HTTP) and Message Queuing Telemetry Transport (MQTT) protocol over the Internet and displayed via interactive...
Android-based mobile user interface (UI). Moreover, information regarding condition and track location of bin can be accessed on website developed using Wix and Weebly platforms. Furthermore, e-mail notification is delivered as bin percentage level reaches 80% full. However, for more system improvement, Low Power Wide Area Network (LoRaWAN) technology can be implemented into the system to increase its connectivity from the range of 10 km. Hence, this can help users with poor Internet access problem. Lastly, more dataset features in cloud server can also be stored and retrieved, such as daily, monthly, and yearly record of mobile e-waste. These statistical dataset can enhance e-waste data management efficiently.

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References

[1] N. Min-Allah & S. Alrashed, “Smart Campus-A Sketch,” in Sustainable & Societies, vol. 59 (102231), 2020, pp. 1–15.
[2] D. H. Abdulmohsin, et al., “Body-to-Body Cooperation in Internet of Medical Things: Toward Energy Efficiency Improvement” in Fut. Inter., vol. 11, 2019.
[3] I. Ahmed, et al., “A Robust Features-Based Person Tracker for Overhead Views in Industrial Environment” in IEEE IoT J., vol. 5 (3), 2018, pp. 1598 - 1605.
[4] M. I. Ahmad et al., “FPGA based Control IC for Multilevel Inverter” in Proc. of 2008 Int. Conf. on Comp. & Comm. Engr., Kuala Lumpur, 2008, pp. 319-322.
[5] H. A. Rahim, et al., “Vehicle Speed Detection using Frame Differencing for Smart Surveillance System” in Proc. of 10th Int. Conf. on Info. Sc., Sig. Proc. & App., Kuala Lumpur, 2010, pp. 630-633.
[6] S. R. M. Zaini & K. N. A. Rani, “Wearable Inset-Fed FR4 Microstrip Patch Antenna Design” in IOP Conf. S. Mat. Sc. & Engr., vol. 318 (012050), 2018, pp. 1-9.
[7] H. A. Rahim, et al., “Evaluation of a Broadband Textile Monopole Antenna Performance for Subject Specific On-body Applications” in Appl. Phys. A, vol. 123 (97), 2017, pp. 1-6.
[8] H. A. Rahim, et al., “Effect of Different Substrate Materials on a Wearable Textile Monopole Antenna” in Proc. of IEEE Symp. on Wire. Tech. & App., Bandung, 2012, pp. 245-247.
[9] S. Shawalil, K. N. A. Rani & H. A. Rahim, “2.45 GHz Wearable Rectenna Array Design for Microwave Energy Harvesting” in Indon. J. of Elect. Engr. & Comp. Sc., vol. 14 (2), 2019, pp. 677-687.
[10] I. Adam, et al., “A Compact Dual-Band Rectenna for Ambient RF Energy Harvesting” in Microwave and Optical Technology Letters, vol. 60 (11), 2018, pp. 2740-2748.
[11] I. Adam, et al., “Double Band Microwave Rectifier for Energy Harvesting” in Microwave and Optical Technology Letters, vol. 58 (4), 2018, pp. 922-927.
[12] C. P. Baldé, et al., The Global E-Waste Monitor 2017: Quantities, Flows, and Resources. Bonn/Geneva/Vienna: UN Univ. (UNU), Int. Tel. Union (ITU) & Int. Solid Waste Assoc., 2017.
[13] World Economic Forum: A New Circular Vision for Electronics Time for a Global Reboot. Cologny/Geneva: Int. Labour Org. (ILO); Int. Tel. Union (ITU); UN Env. Prog. (UNEP); UN Ind. Dev. Org. (UNIDO); UN Inst. for Train. & Res. (UNITAR); UN Univ. (UNU); Sec. of the Basel & Stockholm Conv., 2019.
[14] G. K. Shyam, S. S. Manvi & P. Bharti, “Smart Waste Management using Internet-of-Things (IoT)” in Proc. of 2nd Int. Conf. on Comp. and Comm. Tech., Chennai, 2015, pp. 199-203.
[15] A. Lozano, et al., “Smart Waste Collection System with Low Consumption LoRaWAN Nodes and Route Optimization” in MDPI Sensors, vol. 18(5), 1465, 2018, pp. 1-24.
[16] R. Raj, S. Michael & D. Femi, “Forest Monitoring System through RFID and Tensorflow Object Detection” in Proc. of Int. Carnahan Conf. on Sec. Tech., Chennai, 2019, pp. 1-4.