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iBIN: Intelligent Monitoring System for Recyclable Materials Using Arduino and the IoT

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Abstract: The three R's of the environment, Reduce, Reuse, and Recycle the solid waste, generates significant environmental, economic and health benefits. This work proposes a novel intelligent domestic garbage bin for recyclable materials collection and monitoring, based on the Internet of Things (IoT). IoT refers to the networked interconnection of everyday objects, which are equipped with intelligence. The suggested integrated system uses the intelligence of an Arduino microcontroller and two sensors, and creates the IoT Hub by sending the measurements of the sensors to a remote database. The system manages automatically and on-line the garbage bin, providing information regarding the weight and waste level via a friendly web interface. The web page gathers statistics and rewards, informs and warns the users depending on the amount of recyclables that they have collected in a certain time range.

Keywords: Arduino microcontroller, load cell sensor, ultrasonic sensor, SQL database, Internet of Things (IoT), recyclable waste management.

I. INTRODUCTION

IoT has recently gain considerable attention from researchers globally. Due to the vast progress in underlying technologies, IoT offers infinite possibilities for numerous innovative applications that guarantee to meliorate the quality of modern life [1]. IoT tends to increase the existence of internet in everyday life by integrating embedded systems in items of everyday use. In this work, IoT is utilized to help deal with a serious problem of modern society, the management of recyclable materials. Solid waste management is a challenge for the cities' municipalities since it directly effects, among all, lifestyle, environment, and health. Although recycling requires energy consumption, it is a better solution than disposing the material in a landfill. Waste disposal costs significantly and citizens pay for it through the local taxes. By reducing the amount of waste through recycling, not only the environment is protected, but the local municipality profits from the sale of the recyclable materials to recycling companies. Thus, motivating recycling and managing with the recyclable materials, is a prime concern for local authorities. The ongoing efforts towards this direction are multi-dimensional and primarily premise active participation of all citizens. In New Jersey recycling is mandatory for residents and businesses by legislation [2]. According to the European Directive 2008/98/EC by 2020, the 50% (by weight) of the total produced waste, must be prepared for reuse and recycling. If national authorities of the Member States fail to properly implement EU laws, the Commission may start formal infringement proceedings against the country in question. If the issue is still not settled, the Commission may eventually refer the case to the European Court of Justice [3]. It is a matter of time for all civilized countries globally to introduce similar legislation. The proposed monitoring system for recyclable materials, iBIN, is an intelligent domestic bin, that is made to motivate the residents to recycle and boost their ecological consciousness. It consists of an Arduino microcontroller and two sensors; a load cell and an ultrasonic sensor to detect the weight and level of the recyclable materials inside the bin, respectively. The system also uses a Wi-Fi modem, a Liquid Crystal Display (LCD) to display messages and warning LEDs. The measurements of the sensors are stored in a Structured Query Language (SQL) database and update a web page, providing the users with interesting and necessary information, such as amount of recyclable per capita or per year, online status of the bin, notification in order to get it empty etc. The novelty of iBIN is the introduction of weight information for the recyclable materials. Since the recyclable materials are sold by tons, iBIN gives the possibility to distinguish and award the users that recycle more. The web page displays the overall weight of recyclable material per user, according to which it classifies the users to categories, such as amateur, intermediate, pro or golden recycler. According to these categories, users could potentially get benefits such as special discounts to selected stores (in cooperation with sponsors) or even to local taxes (in cooperation with local administration). Thus, iBIN can motivate recycling, make it competitive among residents, and can further contribute to the development of a more robust recycling system. The use of iBIN in domestic household, can make overall waste management more efficient and environmentally friendly. It is a novel approach to challenge the citizens by providing them statistics, to collect, dispose and recycle the waste.

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II. RELATED WORK

There are several approaches for solid waste management in the literature [4-8]. In [4], the IOT monitoring system uses ultrasonic sensors and informs about the level of collected garbage via a web page. The system utilizes Arduino microcontroller, an LCD screen to display the status of the garbage level, Wi-Fi modem for transmitting the data and a buzzer to inform when the garbage level crosses a preset limit. At that point, a Global System for Mobile communication (GSM) module is used to send warning text messages to the respective authorities.

In [5], an intelligent system for garbage waste bins is suggested. It consists of an Arduino microcontroller that receives and sends signals, of an ultrasonic sensor and a smoke detector, and a GSM module to send alert messages to the user. The ultrasonic sensor is utilized to detect the level of garbage while the smoke detector to detect flame or smoke.

The proposed system in [6] is a bin with a load cell at the bottom to sense the weight of the garbage. It uses LPC2138 microcontroller. It also uses Infrared (IR) sensors to detect the level of garbage. A GSM module is utilized to send message to the garbage depot if the bin exceeds a threshold level.

The smart dustbin introduced in [7] is capable of distinguishing important materials (monetary notes, coins, driving license, debit and credit card) from waste. The smart dustbin can run both on batteries and solar energy, and it is designed to collect the garbage automatically from the ground of an application area, inside which it circulates. An embedded image scanner, scans the image of the materials lying down before disposing them. Images of materials which are considered important are preinstalled inside its memory, and thus, the system is able to identify them.

The solid waste monitoring system described in [8] is designed to serve an entire city. A network of sensors connects the bins with each other, and a real-time interface can inform about the status of all waste bins around the city. The system uses PIC-16F73 microcontroller. Moreover, an algorithm for route planning is suggested, so as the waste trucks to follow the shortest route and deal only with the bins that are full.

Most of the embedded systems in the literature [4, 5, 7] utilize Arduino microcontroller. Arduino is a popular electronic interactive platform at present. Hardware and software are open source and extensible. It is designed for people who are not experts in electronics or programming. Thus, it is simple to use, versatile and affordable, can run in all operating systems and combines simplicity with power [9].

III. SYSTEM ARCHITECTURE AND METHODOLOGY

The proposed system exploits the benefits of an Arduino microcontroller in order to create an innovative solid waste monitoring system. iBIN, is designed to deal only with recyclable materials, such as plastic, paper, glass and aluminium. At this particular time for humanity where the environmental pollution is so extensive, recycling is necessary for the salvation of the planet. The proposed monitoring system intends to awaken the ecological consciousness of people, and make recycling a competitive process among citizens. The status of the iBIN for every user appears in real-time on a web page. Except of current weight and level of recyclable material in iBIN, interesting statistics are also available for every user, such as weight of recyclable material for every past month and previous year so as to compare and check on their recycling progress during years, and total weight of materials that have been recycled according to which the users are divided into categories and awarded. The system alerts the users if the iBIN needs to be emptied both on the web interface that provides visualization of the iBIN's level, but also on the iBIN itself, on an embedded LCD screen that displays the current status of iBIN along with a warning LED that turns from green to red when iBIN is by 90% full. Fig. 1 shows a diagram of the system's architecture.

A. Hardware Analysis and Components

The following components have been utilized for the implementation of the project:

Microcontroller: The main control unit consist of an Arduino Uno microcontroller. It is based on the ATmega328. It has 14 digital input/output pins (of which 6 PWM outputs), 6 analogue inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header and a reset button. Arduino can sense the environment by receiving input signal from the sensors, and controls the LCD screen, LEDs and Wi-Fi Shield.

Ultrasonic Sensor: The ultrasonic sensor HC-SR04 has two pins; trigger and echo. Trigger transmits an ultrasound at 40KHz which travels through air and if there is an obstacle on its way, bounces back to the module. Considering the travel time and the speed of sound (≈340m/s), the distance between the sensor the obstacle can be calculated. The ultrasonic sensor is placed on the top op the bin, so as to measure the level of recyclable materials.

Load Cell Sensor: A straight bar load cell TAL220 is utilized. It can translate up to 10Kg of pressure into electrical signal. Each load cell can measure the electrical resistance that changes in response to the strain applied to the bar, and thus, it is able to measure weight changes. A load cell amplifier HX711 is additionally used. The amplifier helps to read the changes in the resistance of the load cell, and when calibrated, it is able to give very accurate measurements. The load cell sensor is placed on the bottom of the bin, so as to measure the weight of recyclable materials.

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Power Supply: The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, then the 5V pin may supply with less voltage and the board may be unstable. If supplied with more than 12V, the voltage regulator maybe overheated and damage the board. The recommended range is between 7V to 12V. iBIN uses external supply of 9V. A voltage regulator provides 5V for the LCD, LED and the two sensors. The Wi-Fi shield is supplied from the Arduino board with 5V.

LCD: The 16x2 LCD display screen is an electronic display module commonly used for a wide range of applications. It can display 16 characters per line, for 2 lines. Each character is displayed in 5x7 pixel matrix. LCDs are economical, easily programmable and have no limitation of displaying special or even custom characters. The LCD is placed in front of the bin, so as to display constantly the level of recyclable materials inside the bin in terms of the percentage of the bin that is occupied by the recyclable materials. When the percentage reaches the 90%, the LCD displays adequate message so as for the user to get it empty, and at the same time a warning red LED is on.

Wi-Fi Module: Arduino Wi-Fi Shield is open-source hardware. It allows the Arduino board to connect to the internet using the 802.11 wireless specification. It is based on the HDG204 wireless LAN 832.11b/g system in-package. An AT32UC3 provides a network (IP) stack capable of both TCP and UDP. The Wi-Fi shield connects to the Arduino board using long wire-wrap headers which extend through the shield. The measurements of the sensors are sent via the Wi-Fi module at a cloud database, and consequently are retrieved and being used to update the recycling profiles of the users, that is being disposed on line at a web page.

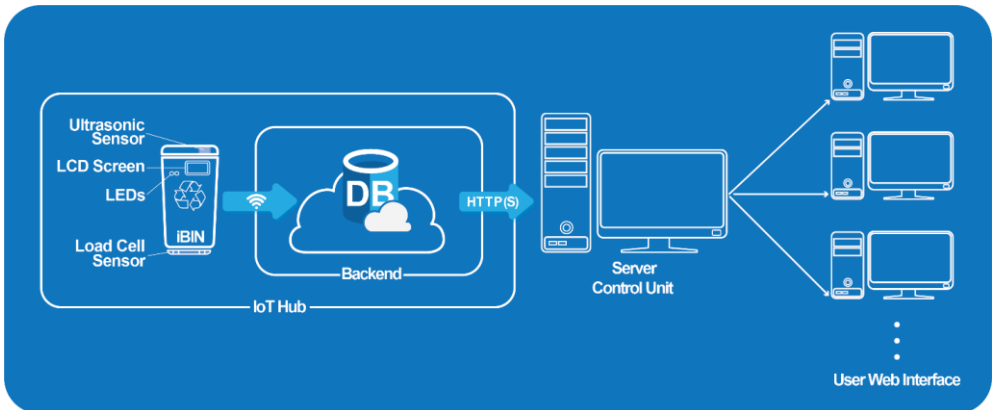

Fig. 1. Architecture of iBIN

B. Software and Web Interface

The microcontroller is programmed using the Arduino programming language (Wiring C) and the Arduino development environment (IDE). Fig. 2 provides the flowchart of the main program.

For the web page creation, programming language HTML is utilized, along with CSS so as to describe the style of the HTML document. These two languages provide the basic structure and style formation used to create the static part of the web page. For the dynamic part of the web page, scripting languages JavaScript and PHP are used. In order to get the data from the SQL server, Report Builder is additionally utilized. Report Builder is a tool for authoring paginated reports. The monitoring of recyclable materials needs the creation of a report definition that specifies where to get the data, which data to get and how to display it. Repost Builder takes the repost definition that the user has specifies, retrieves the data and combines it with the report layout to generate the final report. With the help of Report Builder, the users of iBIN can get an online report of their recycling profiles and the status of the bin, featuring a bar chart diagram for every month of the year that displays the weight of material that they have recycled, a graphical view of the real-time level of recyclable materials inside the bin, and get the statistics from previous years so as to check their progress, regarding consumerism and eco-consciousness.

Moreover, the web page sums up the weight of recycling materials over the years, and based on the total weight, it classifies the users in four categories; amateur, intermediate, pro or golden recycler. The boundaries of the categories have been determined according to the existing data regarding the collection of recyclable materials provided by the Division of Quality of Life, Environment Department, of the Municipality of Kavala, Greece [10]. According to the provided statistics in average on a daily basis, 4.3 tons of recyclable materials are collected from Kavala's blue bins (bins for recyclable materials) network. For a population of 70500 residents that are registered in the municipality of Kavala, the reported amount of recyclable materials corresponds to a daily production per capita around to 61gr. In an annual basis this corresponds to 22 kilos per resident. According to this data, the ranges of the four categories are determined. The ranges for the four recycling categories are presented in Table 1.

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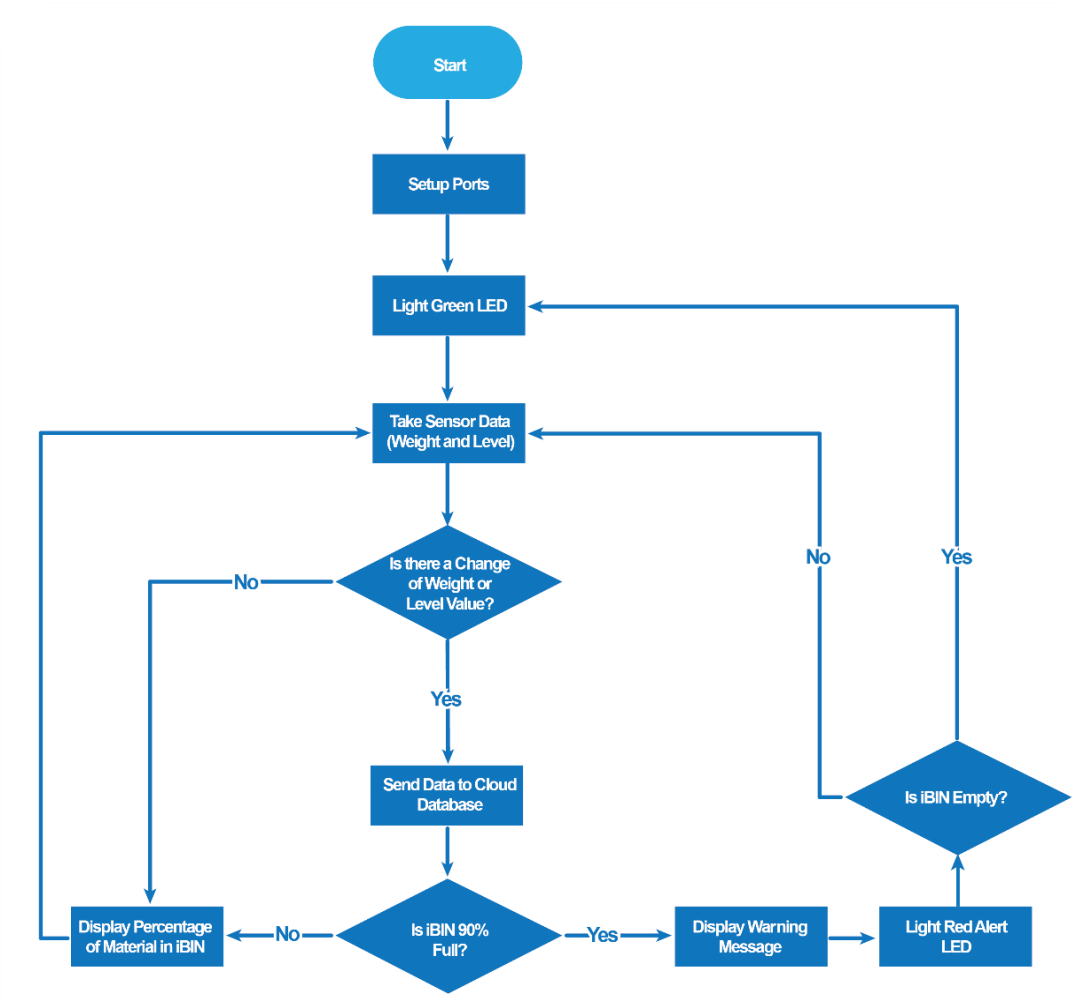

Fig. 2. Flowchart of the program

TABLE I USERS' CLASSIFICATION ACCORDING TO TOTAL WEIGHT OF RECYCLABLE MATERIALS

Categories According to Total Weight (TW in Kg) of Recyclable Materials			
Amateur Recycler	**Intermediate Recycler**	**Pro Recycler**	**Golden Recycler**
0<TW≤50	50<TW≤100	100<TW≤300	TW>300

IV. RESULTS AND DISCUSSION

As the world's population grows, so does the amount of garbage that people produce. Pollution from solid waste has dramatically increased during the last decades worldwide. Materials such as plastic appear interwoven with the modern consuming society. Especially regarding to plastic, accumulation in the environment of man-made plastic products creates severe problems for wildlife and their habitats as well as for humans. Plastic needs hundred years to degrade. Even when it degrades, it does not turn into a form that can be absorbed by nature. It photo-degrades which means that it breaks down into smaller toxic pieces of itself [11]. Recycling needs to be assimilated to everyday routine and lifestyle of people. The proposed embedded system, is a novel approach for monitoring the recyclable materials. It motivates the users to recycle by providing them statistics, and thus, it makes recycling more competitive. A future enhancement of iBIN could include the addition of solar panels so as to run entirely on solar energy. Moreover, a press could be added to iBIN to press periodically the contents of the bin and thereby reduce the volume of recyclable materials within it. When dealing with more iBINs in the city, the reliability of the system can be increased by providing to users special awards depending on their recycling status, either from the city authorities (discounts to local taxes) or from sponsors.

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V. CONCLUSION

In this work a novel domestic garbage bin, iBIN, is introduced. It is designed to deal with recyclable materials such as paper, plastic, glass and aluminium. The collection and monitoring of the recyclable materials is based on IoT. iBIN exploits the benefits of an Arduino microcontroller and utilizes two sensors to record measurements of weight and level of recyclable materials inside the bin, and sent them to a cloud database. The proposed system provides on line monitoring of the bin and information regarding the weight and waste level through a web interface. Merge of iBIN in modern households, promises to increase eco-consciousness of people and make recycling more efficient than ever.

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BIOGRAPHY

Dr. E. Vrochidou received the Diploma [Embedded Systems], the M.Sc [Automatic Control Systems] and Ph.D. [Signal Processing] Degrees from the Department of Electrical & Computer Engineering, Democritus University of Thrace (DUTH), Greece, in 2004, 2007 and 2016, respectively. She is currently a part-time lecturer in the Department of Computer & Informatics Engineering at the Eastern Macedonia and Thrace Institute of Technology (EMaTTech), Greece. Her research interests are mainly in intelligent systems, signal processing and pattern recognition.