A New Smart Waste City Management

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***Abstract*—This paper presents a new method of smart waste city management to provide a clean and hygienic environment to the city residents with a low cost. In this approach, the sensor model is used to read, collect, measure, and transmit waste volume data over the Internet. This data put into a spatio-temporal context and processed by regression, classification, and graph theory. Thenceforth optimization algorithm is used to dynamically and efficiently manage the waste collection. The new method proposed in this work predicts, classifies, and monitors the hazard and amount of waste, respectively. Then, it recommends the priority and optimization of the route to manage the garbage truck efficiently. Finally, to visualize the performance of this method, simulation results are proposed and estimated.**

1. Introduction

A smart city is an urban development vision to integrate information and communication technology (ICT) and Internet of things (IoT) technology which is the way of becoming the next technological revolution [1] in a secure fashion to manage a city's assets. IoT is a framework in which all things have a representation and a presence in the Internet. More specifically, the IoT aims at offering new applications and services bridging the physical and virtual worlds, in which Machine-to-Machine(M2M) communications represents the baseline communication that enables the interactions between things and applications in the cloud such as environment monitoring [2] [3], object tracking [4], traffic management [5], health care [6], and smart home technology [7] [8]. Organizations can use IoT to drive considerable cost savings by improving asset utilization, enhancing process efficiency and boosting productivity. IoT is driven by a combination of forces, including the exponential growth of smart devices, a confluence of low-cost technologies (sensors, wireless networks, big data, and computing power), pervasive connectivity and massive volumes of big data. IoT and big data basically are two sides of the same coin. An IoT device generates continuous streams of data in a scalable way and companies must handle the high volume of stream data and perform actions on that one. The actions can be event correlation, metric calculation, statistic preparation, and analytic. In a normal big data scenario, the data is not always stream data, and the actions are different. In the smart city, waste management is a crucial point for the living environment, and its quality is considered seriously. A possible Smart waste city management system requires a way to cluster the area of trash bin, detect the status of waste in each bin, and a way to process this data. The result of this work will be a valuable input data for the garbage truck management system which can be used to calculate the most optimal route to prevent the hazard of damage, pollution of waste, and resource consumptions.

To manage the waste of a smart city, a system incorporates a model for data sharing between truck drivers in the real time to perform garbage collection, and dynamic route optimization was proposed in [9]. A waste collection solution based on providing intelligence of trash cans including sensors and IoT prototype, which can read, collect, and transmit trash volume data via wireless network was proposed in [10] [11]. This data put into a spatio temporal context and processed by graph theory optimization algorithms that is used to dynamically and efficiently manage waste collection strategies. An adaptive large neighborhood search algorithm for finding optimal cost routes of garbage trucks such that all trash bins are emptied, and the waste is driven to disposal sites while respecting customer time windows is presented in [12]. An improved dynamic route planning is discussed in [13] where the authors enhanced a guided variable neighborhood threshold meta-heuristic adapted to the problem of waste collection. On the other hand, the most important part of a waste management system is the smart bin [14] [15] [16] which collect the data of waste by using sensor and send them over the internet to the server for monitoring the volume of waste. While the network of ultrasonic sensors enabled smart bins connected through the cellular network generates a large amount of data, which is further analyzed and visualized at real time to gain insights about the status of waste around the city [14], a Smart waste management with self-describing objects can detect the kind of waste based on its Radio-frequency identification (RFID) information [15]. However, they don't know the hazard of each bin such as explosion or flame from the bottle of perfume, chemistry, batteries, and electronic wastes. In [16], a hazard detection method was proposed to detect and prevent these issues. Hence, a waste city management process was conducted by an optimal routing garbage truck algorithm based on a given status of the smart bin. We observed that citizens in the city tend to throw their waste into the bins without a certain time of a day. Therefore, a method for predicting the status of each bins will help the city's waste management system to operate more efficiently.

Contributions: This paper presents a new method of smart waste city management to provide a clean and hygienic environment to the city resident. In this approach, each collected data from the recycle bin has been transferred over the Internet to the server which contains the location and status of each bin, respectively. The proposed method is a new smart waste city management which process data from N bins to improve the efficient of garbage truck route. The contributions of this paper are summarized as follows:

- The number of working clusters in each city are optimize and the location of recycle bins are classified automatically.
- A regression algorithm is applied to predict the situation of waste which can reduce the overload trash bin phenomenon while the garbage truck is coming.
- Finally, the priority weight of each bin is considered to improve the efficient of garbage truck routing algorithm.

This paper is organized as the followings: In section 2, a new method of smart waste city management (SWCM) is explained and the structure of the algorithm is investigated. Section 3 presents the SWCM simulation model and it's performance which are used to compare with other method to evaluate our approach. Finally, the related concluding remarks are discussed in section 4.

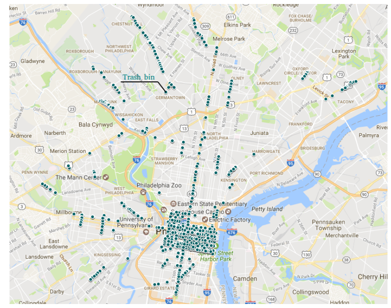
2. IoT-Based Smart waste city management model

2.1. Data acquisition

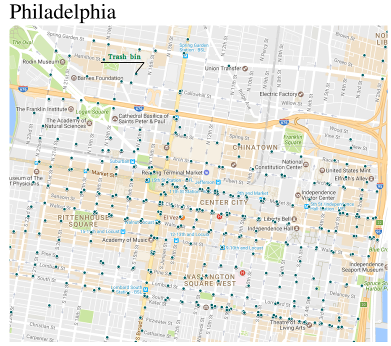
In this section, we describe how to collect waste meta data associated with their status and locations. We choose to evaluate our model with real big data in order to validate its output.

To obtain a set of waste data, we use an open source database, [1] which has a significant amount of geo-location information and status of each bin at the largest city in the Commonwealth of Pennsylvania in the United Stated named Philadelphia. Figure 1 illustrates the distribution of trash bin (green node) in a part of Philadelphia City. We removed the content that was automatically created by stream type service. For data analysis, we adopt the following five essential fields from this meta data:

1. https://www.opendataphilly.org/dataset



(a) The whole distribution of trash bin in Philadelphia



(b) A part of distribution trash bin in Philadelphia

Figure 1: Philadelphia trash bin

- *sn*: Serial number of each bin
- *timestamp*: Milestone of recording data
- *level*: The amount of waset in each bin at the given timestamp
- *lat*: The latitude of each bin
- *lon* The longitude of each bin

2.2. System description

2.2.1. The overview of functionality. The proposed system is based on the waste status of each trash bin in the city. The data collected by sensors is sent over the Internet to the server where it is stored and processed. The collected data is used for monitoring and predicting the status of each bin daily. After that, they will be utilized for calculating the optimal garbage truck routes accordingly. Every day, the system sends the newly calculated routes to the workers based on the waste status, traffic congestion, the state of the forecast, and the balanced cost-efficiency functions. Since the limitation of our data, our optimal garbage truck routes is constructed based on the waste status of each bin. The prediction status of bin can be analyzed based on the given training data before it occurs. The system overview is shown in the Figure 2.

2.2.2. Data processing and classifications. The status of each bin is generally not homogeneous and significantly differs from each other according to the sate of each location. In this section, we introduce an algorithm that can be

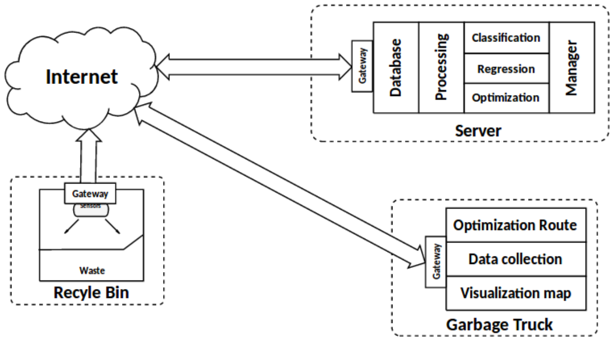


Figure 2: The smart waste management system overview

used to dynamically and efficiently manage waste collection strategies.

K-means [17] is an unsupervised machine learning algorithm that groups a dataset into a user-specified number (k) of clusters. We use it to make the working cluster of each garbage truck. However, this algorithm is somewhat naive, it clusters the data into k clusters, even if k is not the right number of clusters to use. Therefore, when using k-means clustering, users need some way to determine whether they are using the right number of clusters. In this paper, we use Elbow method [18] to validate the number of clusters. The collecting routes are the travelling cycles containing a given set of trash bins. The optimization of these cycles is a combinatorial optimization problem. When the objective function of this optimization is to minimize the driving distance. By considering the large number of routes, we use Genetic algorithm (GA) [19] which are relatively fast in providing near optimal solutions. Since the garbage truck needs time to collect every trash bin, it is very delightful if a status of trash bin can be predicted. Hence, after predicting, the system will recommend which one should be collected to prevent the overload case. In this paper, we use the Linear regression algorithm (LR) [20] to predict the status of each trash bin based on the historical data with a certain confident.

The overall procedure is summarized in Algorithm 1. In this algorithm, the parameters are defined in Table 1. We suppose that the input dataset $\mathcal{D}$ is the database in 2.1. The parameter η, n, d and k denotes the threshold of amount waste in each bin, the number of bins, the time stamp of collecting data, and the number of working clusters, respectively. At here, when a status of the trash bin in a cluster s_{jh} is greater than the given threshold η, the weight of this one will be updated to 1, then the GA algorithm minimizes the driving distance for visiting the selected bins and returning to the headquarters.

On the other hand, at the given time stamp t', a linear regression algorithm is applied to predict the status of each bin. If the prediction status of bin is greater than the given threshold η, the weight is updated to 1, accordingly. Therefore, we can find a new optimal garbage truck routes which help us to prevent the overload trash case.

TABLE 1: The definition of each variable

Variable	Description
$W = \{w_i \mid i \in (1,n)\}$	The weight of each bin
$T = \{t_{di} \mid d \in (1,m); i \in (1,n)\}$	The collected data milestone of each bin
$\mathcal{D} = \{S, L, W, T\}$	The input data
η	The threshold of amount waste in a bin
$\mathcal{M} = \{M_j \mid j \in (1,k)\}$	The optimal route of each garbage truck within each cluster
$\mathcal{DC} = \{DC_j \mid j \in (1,k);$ $DC_j = \{S_j, L_j, W_j, T_j\}\}$	The working cluster

Algorithm 1

Input: $\mathcal{D}, \eta$
Output: $\mathcal{M}$

```
Initialization:
k = Elbow (D →L)
DC = K-means (D →L, k)
At a given time stamp t in the original data.
for j = 1 to k do
    for h = 1 to size(DC_j) do
        if (s_jh ≥ η) then
            w_jh = 1
            M_j = Optimalroute (DC_j → L_j, DC_j → W_j)
        end if
    end for
    Plot (M_j)
end for
At a given time stamp t' in the near future.
for j = 1 to k do
    for h = 1 to size(DC_j) do
        s'_jh = LinearRegression(DC_j → S_j, DC_j → T'_j)
        if (s'_jh ≥ η) then
            w_jh = 1
            M'_j = Optimalroute (DC_j → L_j, DC_j → W'_j)
        end if
    end for
    Plot (M'_j)
end for
```

3. Analysis result and discussion

In this section, using the proposed Algorithm 1 in Section 2.2, we first analyze the number of working cluster and then show the experimental result. We simply assume $\eta = 0.5$, which can also to be set another value to monitor the amount of waste.

3.1. Number of working cluster

One method to validate the number of clusters is the Elbow method. It looks at the percentage of variance explained as a function of the number of clusters: One should choose a number of clusters so that adding another cluster doesnt give much better modeling of the data. In our work, we choose $k \in [1; 15]$. To estimate the optimal value of k, we consider the ratio $\frac{BSS}{TSS}$, where BSS and TSS are

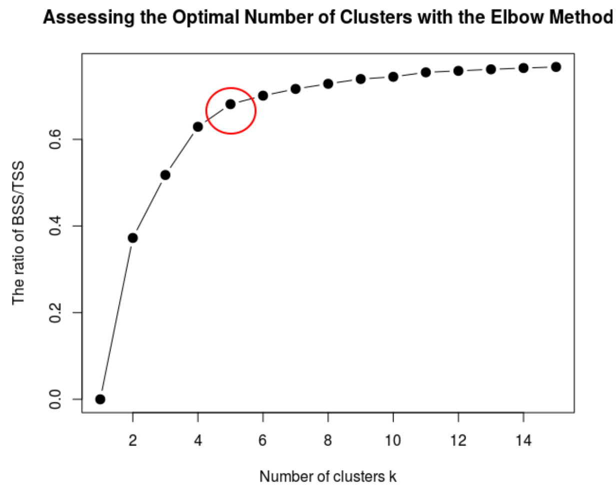


Figure 3: The optimal value of number working clusters

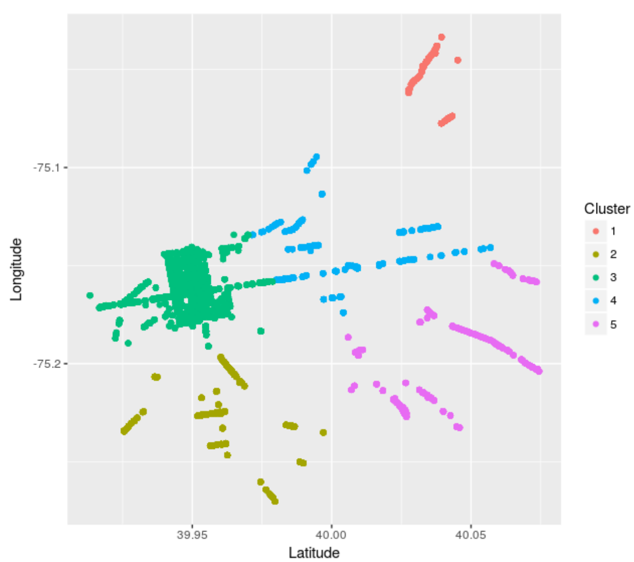
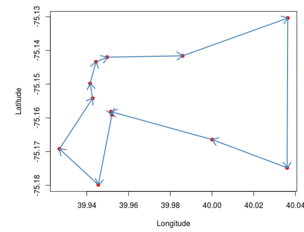


Figure 4: The working clusters in Philadelphia

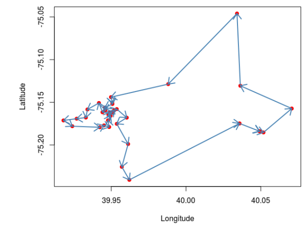
the between and total sum of squares, respectively. A good choice value of k is considered if this ratio tends to change slowly and remain less changing as compared to other k's [2]. We see a pretty clear Elbow at $k = 5$, indicating that 5 is the best number of clusters.

Using the value of k above, we apply the K-means algorithm to make the working clusers for our system. The output is represented in the Figure 4. If the manager tend to add more trash bins into our system, the system will automatically classify them to the each cluster.

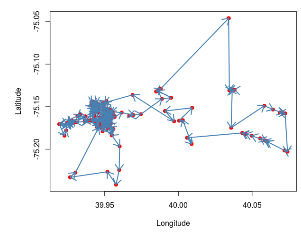
2. https://www.r-bloggers.com/finding-optimal-number-of-clusters/



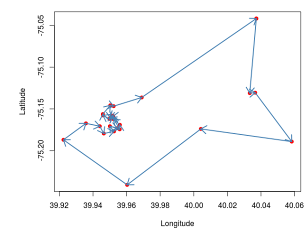
(a) Cluster 1



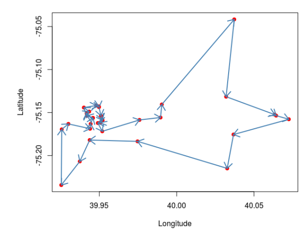
(b) Cluster 2



(c) Cluster 3



(d) Cluster 4



(e) Cluster 5

Figure 5: The optimal route of garbage truck at 2014/06/16

3.2. Optimal route of garbage truck in each cluster

In the each dataset $\mathcal{DC}_j$, where $j \in [1 : k]$, we observed that the original system has three levels of bin such as RED, YELLOW, and GREEN.

Since we need to update the optimal garbage truck routes daily, so we would like to pick up a milestone randomly which is “2014/06/16” in our dataset to make the simulation. The optimal garbage truck routes of each working cluster are presented in the Figure 5.

4. Conclusion

The conclusion goes here.

Acknowledgments

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