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Solid Waste Tracking and Route Optimization using Geotagging and K-means Clustering

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Abstract

Solid waste collection and disposal is a major problem faced by municipalities, hospitals, factories, flats, villas, companies etc. In this paper, a geotagging- and k-means clustering-based approach is proposed to aid in waste collection and management process. An Android application, Solid-waste Acquisition Informer (SAI) is developed which provides an opportunity to every individual to contribute to the process. By using this application, one can send images of Waste Accumulation Areas (WAAs) along with the location details using a GPS-enabled smartphone to the concerned authority which can then take necessary actions to initiate the waste collection process. The proposed system uses GPS information to gather location information, validates the image using an image classification algorithm to roughly identify the type of waste accumulated and then uses K-means clustering algorithm for route optimization finally to help the waste collecting agencies to track the waste-dumped areas. K-means clustering method helps in identifying different clusters from among the scattered locations. It also facilitates tracking of routes which require frequent attention and thus helps in route optimization. The application aims at extending a helping hand to our local governing bodies in their initiatives to clean our locality and make our country cleaner, healthier and smarter. The images of waste accumulation areas in and around Ernakulam city were gathered using the application for testing purposes and found to give good results.

Keywords: Solid waste management; waste collection; geotagging; k-means clustering; image processing.

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1 INTRODUCTION

Waste management is becoming a nightmare for citizens and local authorities in cities across India. It includes collection of wastes from different sources, transporting them to proper centres for waste segregation, recycling and disposal together with careful monitoring and regulation. We often see carelessly thrown and accumulated waste in public places like roadsides, railway stations, bus-stands, backyards of hospitals, hotels, apartments, factories, river sides and where not. As per a study done in 2006, the daily urban municipal solid waste generation per capita per day is 0.46 Kg in India [1] whereas the average daily per capita waste generation is 0.178 Kg in Kerala [2]. However, there is high variation in this value across different areas in the state. In Kerala alone, more than 8000 MT of waste is generated per day out of which only 20.85% is collected and treated [3]. The pace at which solid waste is generated is much higher compared to the pace at which the waste is managed which is highly alarming and needs immediate attention. The local governing bodies alone cannot manage the whole scenario.

Participation of each and every citizen is a must to eradicate the danger posed by the enormous amounts of unhandled waste. Solid-waste Acquisition Informer (SAI) is a waste management service which aids in this waste collection by acting as an information provider to waste collecting agencies that would acquire the waste, separate them, recycle or refurbish a portion of it and may dispose the rest using appropriate methods or even at landfills. Though, municipalities have incorporated their own ways to collect wastes from residential areas like apartments or villas, and some commercial firms, little effort has been taken to collect waste from other public places and rural areas. Local government bodies refrain from an extensive waste collection process mainly due to the fact that all the waste has not been accumulated at a single place but spread out unevenly at numerous places which may also include places unreachable by proper transport. Lack of information also prevents local bodies from refraining from decentralized waste collection. The significance of the proposed system lies here. It mainly aims for a solution for the waste collection in public places. Using SAI application, anyone can send the geotagged image of a Waste Accumulation Area (WAA) to a concerned authority which can then initiate the waste collection process.

The rest of the paper is summarized as follows: Section II gives an overview of existing applications for waste management and limitations of the existing methods. Section III provides the methods and implementation details of the SAI application. Section IV gives the results and discussions and section V gives conclusion and future work.

2 EXISTING WASTE MANAGEMENT SYSTEMS

Waste management systems have been implemented in many countries in many different ways. Many applications have been developed so far [4-6] to aid in waste management process by helping people schedule waste collection, transportation, storage and plan recycling or disposal strategies of which a few are described below. WasteConnect and Reconnect help users to keep track of their recycling schedules and also know about how to properly dispose a particular type of waste. County Waste and Recycling helps users to select recycling locations, set up reminders, pay their bills etc. iRecycle also enables users to choose recycling locations and get suggestions regarding recycling of various materials. Recycle App helps with recycling, and is a guide on how to differentiate waste and dispose each type of waste. WM (Waste Management) mobile application helps to manage the waste management accounts easily, pay the bills, view pick-up schedule, manage payments etc. Rethink Waste and My Waste are Android applications that help to keep track of waste collection by providing schedule of waste collection programmes, events, awareness programmes etc. customized to your location. Delta Waste System helps in managing accounts, container tracking, routing etc. Enablon waste management software also helps to manage and reduce waste. Geoware waste management software is a software solution to manage and track all material flows in and out and within the waste management sites. Intelex waste management software helps to easily track and report on the various stages of waste management and disposal. Trux, a waste management software application developed for the waste recycling companies, provides routing, scheduling, dispatch, billing, account management, and sales reporting. Waste Information Server (WIS) is a cloud-based server for domestic waste collection which includes customer location tracking using GPS, managing and tracking all staff as well as all the daily processes and managing all documentation and accounting.

Some of the waste management systems use sensor technology and manages waste collection using smart wireless sensors to collect the information regarding accumulation of waste in waste containers (eg; Enevo, SENSdumpster, Smart Waste Management System) [7]. Enevo automates the planning of waste collection and also performs route optimization. Wireless ultrasonic sensors are used to remotely measure the fill-level of waste containers and a cloud service is used to forecast when the bins become full and optimize the collection routes and schedules. SENSdumpster is a fully ZigBee wireless device which apart from monitoring the fill-level of containers helps detect possibility of fire using a temperature sensor that can detect steep rise in temperature. Smart Waste Management System helps to schedule the waste collection from various containers using information from sensors and also track and penalize workers failing to collect the waste at proper time.

All the waste management applications discussed so far, are only for known waste sources and not for unmanaged, and scattered waste. Even though there are many applications which aid in waste management process by helping the users track the waste collection schedule, set reminders, pay bills, receive suggestions on recycling different types of materials etc., seldom have been developed which helps in locating every nook and corner where large amount of waste have been dumped carelessly. The proposed system aims to achieve this through the active participation of every responsible individual who registers as a user of the application. SAI acts as an alerting service to the waste collection agencies and also sends information of dumpyards to corresponding higher authorities and involves in waste collection directly. It acts as a mediator between the common man and waste management authorities.

3 METHODS AND IMPLEMENTATION

3.1 Basic Block Diagram of SAI

The basic block diagram of SAI application is shown in figure 1. It mainly involves three parts: User Device, server and authority device. Fig. 2 shows the process flow for the SAI application. The GPS-enabled (Global Positioning System) user device captures the image which is geo-tagged at the same instant. It automatically fetches the location details which include latitude, longitude, place, date, time etc. A nearest landmark is also provided by the user which is optional. Latitude, longitude, and nearest landmark are then embedded as text into the image. The image of WAA is compressed, embedded with location information and sent to the server along with all details passed as parameter values. At the server side, the images are validated and only those images taken of WAAs are processed further. Latitude and longitude information are extracted from the image along with the landmark. These are used to exactly locate the place in the image and are also used to trace the route to the location specified with the help of Google Map and hence provide a notification to the concerned authority, along with the route map or URL.

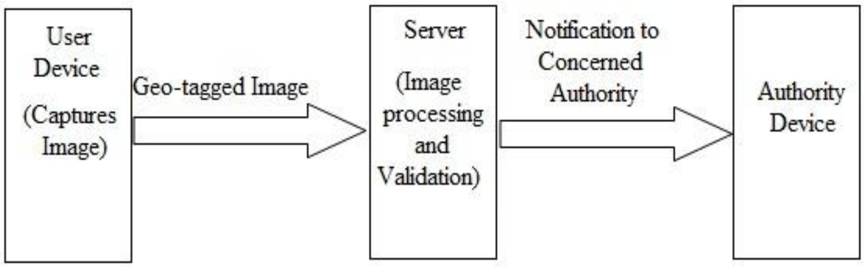

Fig. 1. Basic block diagram of SAI.

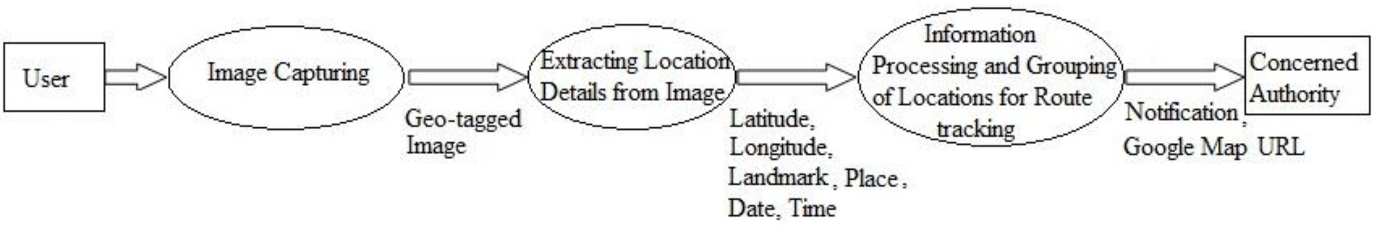

Fig. 2. Process flow of SAI.

3.2 Image Processing for Mobile Applications

An application user can take a picture under different circumstances and hence the image recognition algorithms have to be invariant to changes in illumination and viewpoint. There are different image processing techniques available for mobile applications. A database of multiple viewpoints' images is used in [8] for matching and recognizing the landmarks captured through camera phone with the help of GPS. SAI also makes use of such a database.

3.3 Automatic Geotagging of Images using GPS

Geotagging is the process of adding geographical information to images, messages, videos etc. in the form of metadata. This metadata includes location details like latitude, longitude, altitude and also place names, timestamp etc. It can thus help users find location-specific information [9]. The paper also discusses on how the different geographical knowledge databases can be used for different applications like event, object, place, season identification etc. using classifiers or pattern recognition algorithms, popular place recommendation, and reverse geocoding. It focuses on: modalities in which geographical information can be extracted, applications that benefit from the use of geographical information and the interplay between modalities and applications.

In SAI system, a GPS-enabled smartphone is used for obtaining geotagged images. Image is geotagged automatically at the time of capturing, with the help of GPS, and then uploaded to the server. The geographical location information in the image enables the receiver to infer the location of the image.

Geotagging poses a major issue regarding the storage of images. Many geotagging applications have to deal with the size and nature of the image database. Location Aware Self-Organizing Map (LASOM), an unsupervised clustering method, is used to compress the large image database and learn similarity relationships between different geographical locations [10]. It can compress large amounts of data by storing only the features that are required for discriminating one geographical region from another. This method is also found to give better results than K-Nearest Neighbor approach. SAI also performs a simple image compression before embedding text information and sending it to the server.

In [11], the authors discuss on another aspect of geotagging – associating geographical information to named entities in online documents. It deals with how efficiently the geographical information of a named entity can be resolved at a location granularity, given the entity and a set of pages where the entity is mentioned. The study shows that such a name can be estimated with a good accuracy based on detection of a geocentre.

3.4 Image Transmission

In SAI, the picture captured by the user has to be transmitted to the corresponding authority. Image transmission can be defined as the process of transmitting a picture from a transmitter. Secured transmission of an image involves the following steps:

a) sub-dividing an image into n number of sub images of size p x q

b) finding a suitable permutation/combination to interchange the pixels

c) merging the sub-images into a single image and transmitting it

At the receiver side, the received encrypted image is sub-divided into n number of sub-images of size p x q, the original pixel positions are obtained and the original image is formed. The effectiveness of the technique is measured in terms of correlation index and entropy for different rules of permutation [12]. File Transfer Service (FTS) for mobile applications is a service that allows mobile applications to store and request files from an external storage server, taking advantage of available wireless networks and considering issues related to the cost of the service [13].

3.5 K-means Clustering for Identifying Clustered Locations and Finding Optimized Route

K-means clustering is an unsupervised learning algorithm used to group datapoints into a given number of clusters by minimizing the sum of squares of distances between datapoints and their respective cluster centroids [14]. It is a partitioning algorithm, which when given D, a set of n objects, and k, the number of clusters to form, organizes the objects into k partitions, where each partition represents a cluster [15]. k is a user-specified parameter. The resulting clusters are such that the intra-cluster similarity is high, but the inter-cluster similarity is low.

The algorithm works as follows: k centroids (cluster means) are chosen initially from the set of datapoints under consideration and every other point is assigned to the nearest centroid. Euclidean distance can be used as a proximity measure for assigning points to centroids. For every point, its Euclidean distances to all the centroids are computed and it is assigned to that centroid which is the closest. Points assigned to the same centroid are said to form a cluster. Once all the points get assigned to any and exactly one of the clusters, the cluster centroids are recomputed and the points are reassigned to form refined clusters. This process repeats until there is no more reassignment of points to centroids or change in centroids or when the criterion function converges. The square-error criterion used is defined [15] as,

$$E = \sum_{i=1}^{k} \sum_{p \in C_i} |p - m_i|^2. \quad (1)$$

where E is the sum of the square error for all objects in the dataset; p is the point in space representing a given object; and m_i is the mean of cluster C_i (both p and m_i are multidimensional).

4 RESULTS AND DISCUSSION

4.1 Image Capturing and Processing

A user who wishes to capture images has to initially register his mobile number. OTP verification is also provided for authentication. Every registered user has a user identifier. This user ID also gets stored in the server database along with the details of the images uploaded by him. This helps to track people who upload junk images and also to send back a warning message to him, if required. User who captures the image can also add a landmark for exact location identification. The latitude and longitude values help to retrieve the Google map URL for the location. However, an added landmark can figure out the exact location.

Fig. 3 shows a geotagged image with latitude, longitude and nearest landmark embedded on it. The notification received by the authority device also includes the image description extracted from Google for the image and has the Google map URL to locate the place where the image was captured.

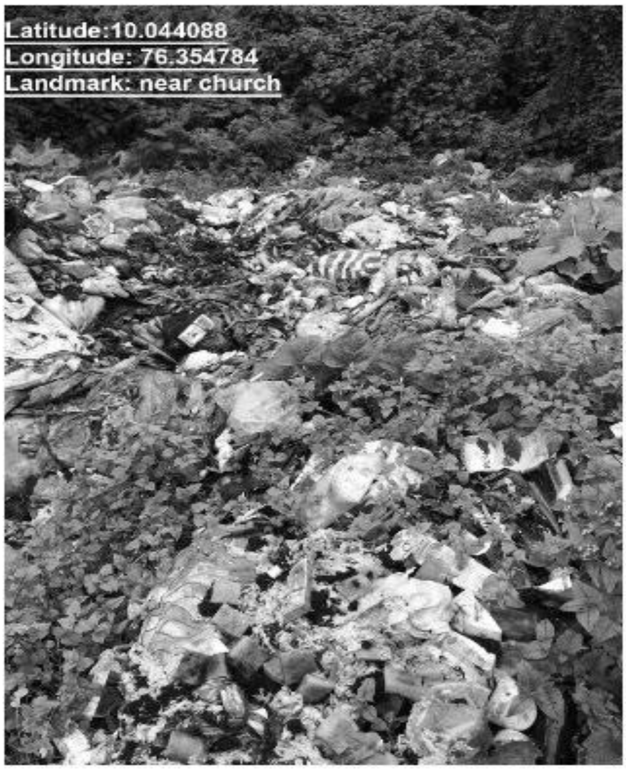

Fig. 3. Geotagged image

Fig. 4 shows the information obtained from the geotagged images. A total of 200 images were captured from different locations (including overlapping images), out of which only a few are listed here. It includes latitude, longitude, nearest landmark, place, date and time, and the Google map URL for every image captured. The database stores only valid images. Administrator has the privilege to delete invalid images based on either the preview of the image or based on the image description extracted for the image from Google. The nearest landmark and place is used for the purpose of verification and grouping of locations manually by an authorized person, if required, to facilitate optimized route tracking.

A	B	C	D	E	F	G	H
Image Object	Latitude	Longitude	Nearest Landmark	Place	Date & Time	Image URL	Image Descripti
1	9.899799	76.377007	Under Bridge, Nadakkavu	Ernakulam	3/18/2017 10:35	http://maps.google.com/maps?q=9.899799,76.377007	assorted item lot
2	9.972822	76.336889	Near Junction	Eroor	3/18/2017 15:38	http://maps.google.com/maps?q=9.972822, 76.336889	assorted junk on the street
3	9.926354	76.375265	Road Side	Kureekkad	3/18/2017 16:35	http://maps.google.com/maps?q=9.926354,76.375265	garbage beside the road
4	10.044088	76.354784	Near Church, Kangarappady	Kangarappady	3/18/2017 17:25	http://maps.google.com/maps?q=10.044088,76.354784	garbage near church
5	9.9263563	76.3178649	Opp. Focus Hero Serv	Kochi	3/19/2017 18:03	http://maps.google.com/maps?q=9.9263563,76.3178649	garbage on ground
6	9.9263563	76.3178649	Near Focus Hero Serv	Kochi	3/19/2017 18:10	http://maps.google.com/maps?q=9.9263563,76.3178649	garbage near brown tree
7	9.9391812	76.3297949	Near Nucleus Mall, Ma	Ernakulam	3/19/2017 18:12	http://maps.google.com/maps?q=9.9391812,76.3297949	garbage mixed with dried leaves and gree
8	9.9440826	76.3382213	Near SNV School	Thrippunithura	3/19/2017 18:16	http://maps.google.com/maps?q=9.9440826,76.3382213	assorted plastic pack
9	9.9440826	76.3382213	Near RLV College	Thrippunithura	3/19/2017 18:19	http://maps.google.com/maps?q=9.9440826,76.3382213	pond filled with withered leaves and garb
10	9.9499467	76.356312	Near Thiruvankulam	Kochi	3/19/2017 18:33	http://maps.google.com/maps?q=9.9499467,76.356312	plastic bag lot near gray wire fence
11	9.880304	76.421969	Near Temple	Ozhakkode	3/20/2017 12:13	http://maps.google.com/maps?q=9.880304,76.421969	garbage lot blocking the water flow
12	9.898891	76.373981	Near Bridge	Nadakkavu	3/21/2017 12:30	http://maps.google.com/maps?q=9.898891,76.373981	white goat beside garbage
13	9.8843484	76.2964712	Aroor Industrial Area	Kochi	3/22/2017 13:26	http://maps.google.com/maps?q=9.8843484,76.2964712	photo of garbage items near green plant

Fig. 4. Geotagged image information captured by SAI application

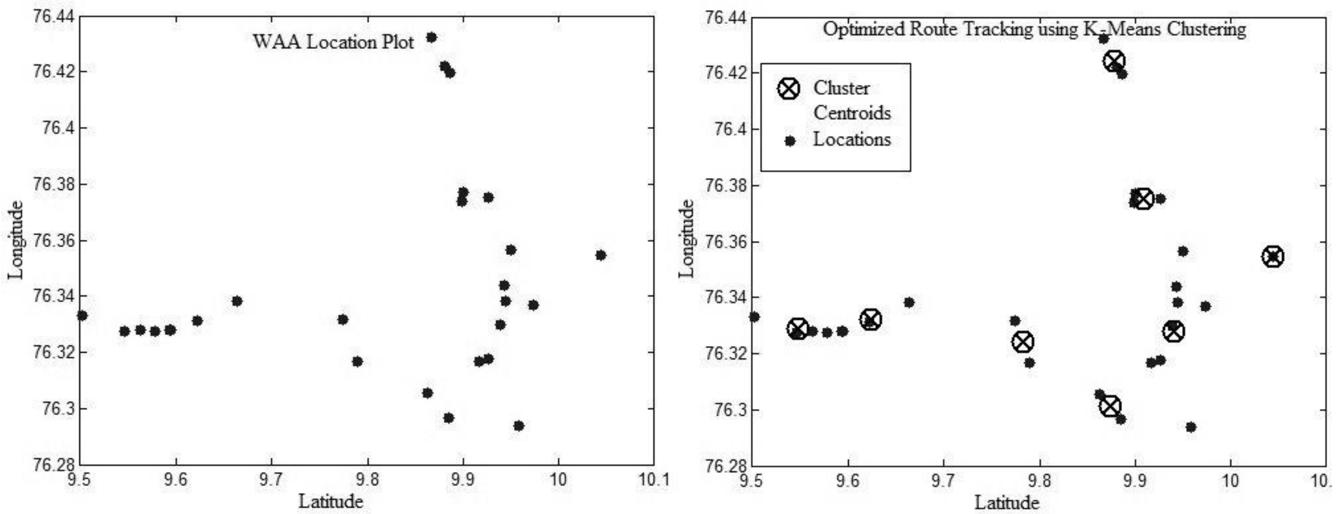

Fig. 5. Optimized route tracking using K-means clustering

4.2 Optimized Routing using K-means Clustering

Place name helps to manually identify those areas which are closer to each other and therefore helps to decide the optimized routes that have to be taken for waste collection. The concerned authority can then initiate the waste collection process based on the data received from the server. Route optimization can be automated using the latitude and longitude values obtained from the images and the optimized route can also be traced using Google map. In SAI, k-means clustering is used to identify locations which are close to each other and hence help in route optimization.

Fig. 5 shows the result of applying k-means algorithm to a set of data. The dataset contains latitudes and longitudes (location information) for 200 locations. Some of the datapoints in the set are overlapping due to two reasons: a) these may be images of the same location taken on different days or at different times b) these may be images of locations which are extremely close to each other.

K-means clustering is done to identify clusters in the set, that is, the locations which are closer to each other. In the optimized route, the k cluster centroids are considered as the main locations. The value of k, which is taken as the number of main waste collection points, can be set by the administrator based on the total number of WAAs in the dataset. It also keeps track of the number of locations associated with each cluster centroid which is the number of locations to be covered near a main collection point and which helps to roughly estimate the amount of waste that might have accumulated around that region. Once the waste is collected, the information corresponding to those WAAs are removed from the database as the new entries keep on accumulating.

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4.3 Other Applications

There are a variety of other applications where the proposed method can be used. A few examples are:

a) To inform water authority about a broken water pipe along the road side, one can take an image geotagged and embedded with location information as well as date and time and send notification to a concerned number.
b) To inform the traffic control room about any violation of traffic rules or signals by anyone, one can immediately take an image of the vehicle and upload it or send it to concerned authority.
c) To inform about accidents or any untoward incidents, one can immediately take an image of the site and send notification to concerned number.

5 CONCLUSION

In this paper, a geotagging-based waste management service is proposed which provides information regarding Waste Accumulation Areas (WAAs) to the concerned authorities. It also helps the waste collecting agencies to decide on the optimized routes. The application is easily manageable by a layman since from the user’s point of view, it requires no special knowledge other than taking a simple photograph using a mobile camera. It can thus be used by all types of users and enables active participation of every individual in waste management. The application also validates the image at the receiver end and stores it and processes it only if it has authenticity and if it really is that of a WAA.

As future work, an image classification and segmentation feature can be added to the system which can segment the image into different parts and identify the types of wastes involved, whether electronic wastes, other solid wastes, organic and inorganic wastes, medical wastes etc. Based on the information obtained from the segmented image about the types of wastes, recycling or disposal tips as well as information about waste collecting or recycling agencies can be provided to the user so that he himself can contribute to waste disposal in a more efficient manner. This feature would be very useful for disposal of household wastes and thus extending a hand further and farther to build a cleaner, healthier and smarter society with the help of each and every individual in the society.

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