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Smart Waste Collection System Based on Location Intelligence

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Abstract:
Cities around the world are on the run to become smarter. Some of these have seen an opportunity on deploying dedicated municipal access networks to support all types of city management and maintenance services requiring a data connection. This paper practically demonstrates how Internet of Things (IoT) integration with data access networks, Geographic Information Systems (GIS), combinatorial optimization, and electronic engineering can contribute to improve cities' management systems. We present a waste collection solution based on providing intelligence to trashcans, by using an IoT prototype embedded with sensors, which can read, collect, and transmit trash volume data over the Internet. This data put into a spatio-temporal context and processed by graph theory optimization algorithms can be used to dynamically and efficiently manage waste collection strategies. Experiments are carried out to investigate the benefits of such a system, in comparison to a traditional sectorial waste collection approaches, also including economic factors. A realistic scenario is set up by using Open Data from the city of Copenhagen highlighting the opportunities created by this type of initiatives for third parties to contribute and develop Smart city solutions.

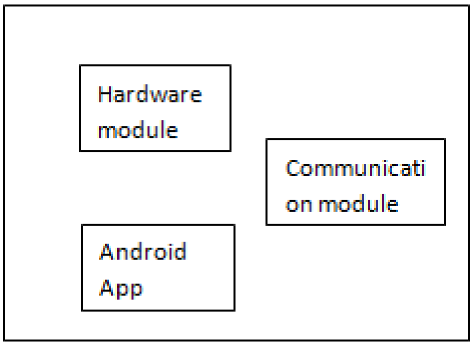
Keywords: Location Intelligence, Smart City, Internet of Things.

1. INTRODUCTION

We are currently experiencing a fast development of Smart Cities where engineers, urban planners, architects and city managers are joining forces with the goal of boosting up the efficiency of municipal services and increasing benefits and convenience to their communities [1]. In this case, efficiency may be related to a wide spectrum of factors such as quality of life, economy, sustainability, or one of the key enablers for Smart Cities/Societies regardless of the context or specific goals of each individual service, application or action under this umbrella [2]. In this paper, we describe how an integrated cyber physical system design, based on the combination of different disciplines in engineering, and taking advantage of municipal wireless access networks can lead to smart ways of improving the management of cities. The proposed system lays over the foundation of Geographic Information Systems (GIS), applied graph theory on graph optimization, and machine learning. It consists of an IoT based prototype with sensors measuring the waste volume in trashcans or containers, with the capability of transmitting information to the Internet via a wireless link. This data is used to optimize the management and strategies of waste collection logistics. The system is simulated in a realistic scenario in the city of Copenhagen, and using freely available geolocation data of the municipality owned trashcans as Open Data [3]. The simulation covers a period of one month where trashcan filling and waste collection are modelled. The experiments are carried out performing an efficiency comparison of two different ways for waste collection: Traditional sectorial (not-intelligent) and dynamic on demand based waste level status (intelligent). In addition, a preliminary assessment is performed evaluating whether the solution is economically sustainable on its own or not. The outcomes of this work are an integrated system model for intelligent waste collection, and the quantification of its benefits and economic costs when deploying and using it for evaluating its feasibility as a real world Smart City application. In addition, this concrete use case illustrates the enormous potential of Open Data and the opportunities that a unified ICT infrastructure dedicated to Smart City oriented services can provide.

2 .PROPOSED SYSTEM

We propose to develop a Smart Garbage Bin to intimate the officials about full garbage bins. The system uses Raspberry Pi and Ultrasonic Sensors for determining the amount of garbage in the bin and intimating the officials through a Web Interface or Android App.



1. Hardware module:

- Continuously keep a watch on the level of garbage in the bin and update the database.
- Update database is case the bin is 80% full in a special column by using python language.

2. Android Module:

- Request the status from all bins and update the user interface.
- If status of any bin is 80% and more, notify. By using Java language.

3. Communication Module:

- Interface between Android and Raspberry pi using php.

3. METHODOLOGY

The system will be installed in the garbage bin lids which will send ultrasonic waves down towards the garbage and receive the reflected waves. Then it calculates the time taken for the reflection. This 'time' can be used to determine the amount of garbage in the bin.

System Architecture

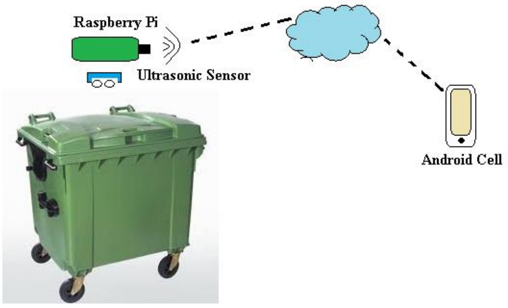


Figure.1. overview of system

The product will perform the following functions

- Continuously keep a watch on the Garbage Bins in the City and the garbage upon reaching a particular height.
- Inform the concern people about it along with its location.

The system and its functions

A) The prototype:

 Sensors: The waste level is determined by measuring the distance from the top of the trashcan to the waste by sonar. The sonar used in the prototype is Ultrasonic Ranging Module (HC-SR04). It can provide measurement from 2cm to 400cm with 3mm accuracy, which adequate for typical trashcans. Additional temperature, humidity and motion, or weight sensors can be installed to increase the efficiency in the future.

Access Network Interface: The data collected must be sent to a remote server via a wireless link. In our prototype we used WiFi as a network access technology.

B) Server:

 Database: Storage of all data collected by the sensors and the trucks, MySQL was employed for our setup.

 Artificial Intelligence: The forecast of waste levels and learning of how to select the daily cans to be collected is based on historical data.

C) Optimization algorithms:

Every day, after the trashcans to be collected have been selected, route optimization algorithms calculate the best route to follow. In this work, the routes are optimized in driving distance but there are also other possibilities such as to minimize driving time based on historical data on traffic congestion.

 Information adaptation and forwarding: The final routes must be sent to the workers in readable format by visualization devices, for example as a KML file.

D) End user:

 Visualization: The routes are sent to the end user and visualized in common devices such as mobile phones, tablets or navigation systems with data access. In this way the driver can easily follow the routes.

 Data collection: Additional data can be collected from the trucks such as GPS locations and timestamps in order to determine the traffic flow on the different streets. These and other data could be used by the Artificial Intelligence and Optimization Algorithms modules to learn and make better and more efficient can selections and routes.

Shortest Path Spanning Tree (SPST) This algorithm is used to calculate the shortest distance between two points in the area (for example, two trashcans), combined with GIS data of the streets in the city. The street network can be represented as a graph where street segments are edges and the joining points are vertexes. Hence, it is possible to calculate a realistic shortest driving distance between points by applying SPST. The distances are necessary as an input for the route optimization process. For practical reasons, it is convenient to pre compute the distance from all-to-all trashcans to speed up the route optimization process.

Genetic Algorithms (GA):

Collection routes are essentially travelling cycles containing a given set of trashcans. The optimization of these cycles is a combinatorial optimization problem. When the objective function of this optimization is to minimize the driving distance (equivalent to minimizing the length of the cycles), the problem is well known as The Traveling Salesman Problem and closely related to The Minimum Linear Arrangement Problem which are NP-hard [12]. Due to the high number of route optimizations required to carry out the experiments, it was decided to use GA which are relatively fast in providing near-optimal solutions. A detailed explanation of how to use GA for this type of graph optimization problems can be found in [13]. K-means [l4]: Clustering is also an NP-hard problem, especially complex to solve when involving hard clustering size constraints. However, the experiments carried out in this work do not have such constraints and K-means provides an easy and fast solution to the clustering problems to be solved.

4. CONCLUSION

This paper presents a practical Smart City use case of an intelligent waste collection cyber physical system. The system is based on an Internet of Things sensing prototype which measures the waste level of trashcans and sends this data over the Internet to a server for storage and processing. Based on this data, an optimization process allows creating the most efficient collection routes, and these are forwarded to the workers. The paper is focused on the efficiency and economic feasibility of the system, in order to motivate the potential interested parties to deploy intelligent solutions for common city services. The experiments are carried out on a Geographic Information Systems simulation environment, applying graph optimization algorithms and taking advantage of available Open Data about the city of Copenhagen, Denmark. The results indicate that under the same conditions, basing the waste collection strategies on real time trashcan filling status improves the waste collection efficiency by guaranteeing that when trashcans become full, they are collected the same day, and by reducing by a factor of 4 the waste overflow that cannot be accommodated when trashcans are full. However, the distance required to drive is tripled, implying an increment on the daily collection cost between 13 - 25%. In relation to the economic feasibility analysis, the improvement in efficiency by deploying and using the proposed system implies higher total costs. However, when comparing the total costs of the different collection strategies under similar efficiency figures, we have observed that the savings in collection costs for an intelligent solution may cover the extra expenses for deploying and maintaining the system (CapEx and OpEx) in a short term perspective of 2 years. Furthermore, once the system is deployed, the efficiency and collection costs could be further improved when historical data is available for trashcan selection optimization. In relation to future work directions, being aware that the numerical results of the experiments are highly dependent on assumptions considered, a sensibility analysis on the different parameters may provide valuable information about the system's performance in under different conditions. Furthermore, the natural step to take is to test how the use of historical data analysis can improve the efficiency and collection costs of dynamic strategies. Afterwards, if the results are satisfactory, field trials are expected to be conducted.

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