An Auxiliary System for Road Inspection Based on Geotagged Videos and Map Services

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***Abstract*—Road maintenance requires regular and careful road inspection. Therefore, how to perform the large-scale road inspection efficiently becomes a challenging issue. Current solutions to the road inspection typically rely on the mass cost of labor and time. This paper introduces an auxiliary system based on geotagged videos and map services to help road inspectors perform their tasks. With the mobile application, drivers can record street videos when they are driving. The videos can be uploaded to the system on demand. When the inspectors would like to examine the road condition of some specific road segments, the system will process the data and produce the street videos of the corresponding road segments. The inspectors watch the videos and make some arrangements if necessary. Their work process can be simplified. The system has been implemented and tested successfully.**

***Index Terms*—road inspection, location information, mobile device, street view videos, crowdsourcing, GPS tracking, connected car, map services, geotagged videos.**

1. Introduction

The quality of roads has a big influence on the driving experience as well as driving safety. According to the statistics of the Ministry of Transportation and Communications of Taiwan, around two thousands of traffic accidents are related to road anomalies (e.g., potholes and cracks) in 2017 [1]. Therefore, the periodic road inspection is essential for the safety of drivers and passengers. Traditionally, road inspectors are assigned to do visual inspection along the roads. This approach requires a lot of labor and time. In recent years, satellite inspection vehicles equipped with cameras and GPS have been applied in the road inspection. However, the inspection vehicles are extremely expensive. The number of the inspection vehicles in a city is quite limited, so they still cannot provide sufficient workload.

Current mobile devices (e.g., smartphones), containing a camera, the GPS, a microphone, and sensors, have the ability to acquire environmental information. If drivers collect the road condition using their mobile devices and share the collected information, the huge work of the road inspection will be saved.

This paper develops an auxiliary system for helping road inspectors assess road conditions. The system is composed of the mobile application, the website, the server, and the database. Drivers use the mobile application to record videos, location, and speed while they are driving. The gathered GPS data are delivered to the server through the wireless network. The system then analyzes the uploaded data of all participants (drivers). The traversed roads can be shown on the interactive map of the website. When the road inspectors select road segments for inspection, the corresponding videos of the road segments will be uploaded. The videos related in the inspected road segments are then edited (cut and merged), since the inspected road segments may need several pieces of the videos recorded by different vehicles. After the inspectors finish watching the videos, they will have preliminary results and be able to make appropriate arrangements. In this way, the task of the road inspection can be executed more efficiently.

2. Related Work

A citizen reporting system was developed to help road inspectors [2]. When the citizens observe potholes or damaged facilities on the road, they can take pictures of the anomalies by their smartphones. These pictures can be reported to the staff of the road maintenance department through the reporting system. Another similar service, called FixMyStreet, was provided in the UK [3]. This approach is useful for reporting anomalies, but cannot provide the needed regular task of road inspection.

To reduce the demand for labor, satellite inspection vehicles are introduced for road inspection. The satellite inspection vehicles are equipped with GPS modules and the laser scanning systems. The images of the road surfaces can be captured clearly when the vehicles are traveling. The condition of the road surfaces can be assessed with high accuracy [4] [5]. The condition of roads can also be evaluated using the data collected from the equipped sensors [6] [7] [8]. The inspection vehicles reduce the need of the inspectors, but they are too expensive to be widely deployed.

Some smartphone-based approaches [9] [10] [11] [12] were designed for pothole inspection. These approaches typically rely on the measurement of the accelerometer to detect potholes automatically with low false positive. Mobile video recorders and map information are also used for road safety inspection [13]. Drivers use their smartphones to record videos and location information. The videos and information are loaded to the server via a USB cable offline.

3. System Design

A. System Overview

As illustrated in Fig. 1, the developed system consists of four main components, including the mobile application, the website, the back-end server, and the database. The mobile application is responsible for recording videos continuously

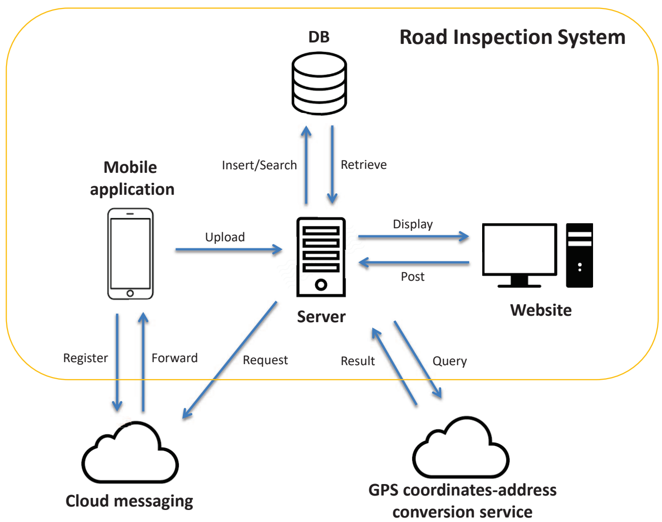


Fig. 1: System overview.

from vehicles. The GPS related data, such as GPS coordinates and speed, are also recorded. The collected data are sent to the server automatically. For saving the communication cost, the videos will be uploaded when needed by the server. After the back-end server receives the data, it will process the data and know which road segments have the videos recorded. The road inspectors can use the website to check which road segments are available for inspection. With the interactive map, the road inspectors select the road segments that they would like to examine. When the road segments are selected, the server will send the "upload video" notifications to the mobile devices through a cloud messaging service. Once the videos are uploaded and edited, the road inspectors can perform their tasks by watching the videos. The database is used to store GPS-related data, route information, and other data which are needed by the server.

B. Mobile Application

When the mobile application is installed on the smartphone, the smartphone will be assigned a token. The token is a registration ID can identify smartphones. The functions of the mobile application include video recording and GPS-related data collection. The GPS-related data, including date, time, GPS coordinates, and speed of the vehicle, are stored in a GPS file. Each recorded video has its correspondent GPS file. Besides the automatic street view recording, the mobile application supports a snapshot function. If the drivers observe damaged traffic facilities or abnormal events, such as potholes, fallen trees, etc., they can take pictures of the anomalies by the voice command or touching the screen of their smartphones. When the video recording is completed, the GPS file and the specified notification will be uploaded to the back-end server. The smartphone typically transmits only the GPS files to the server. If the server needs the corresponding videos, it will send a request to the smartphone. The smartphone then uploads the needed videos to the server through the wireless network.

C. Website

The road inspectors use the website to monitor the road condition. The website is divided into two web pages. One is for choosing the target path for the inspection, and the other is for playing target videos and displaying photos. Both parts are incorporated with map services. The function for each part is depicted as follows.

1) Choose Target Path: The GPS data in each uploaded GPS file are analyzed and converted into a sequence of street names by the server. Each traversed route is shown on the map and also listed on the route pane. The road inspectors can identify the traversed road segments based on the map and the route pane. A route filtering mechanism is also provided for the advanced search. Only the routes that meet the conditions will be displayed on the map and the pane. The inspectors then set the start point and the end point of the target path. The chosen points are sent to the server for path construction and video preparation.

2) Play Target Videos and Display Photos: If the drivers upload photos to the server, the photos will be displayed on the map based on the location where the photos are captured. The target paths are also plotted on the map. The road inspectors can complete the preliminary road inspection by watching the target videos and browsing the photos.

D. Back-End Server

The back-end server is responsible for the computation in the road inspection system. The server not only receives messages from the mobile applications and the website but also returns the computing results. Furthermore, the back-end server also communicates with the database. The tasks performed by the server are described below.

1) Insert GPS Data into Database: When a GPS file and a token are uploaded to the back-end server, the GPS file will be read by the back-end server. According to the number of the routes that have been stored in the database, the GPS file is assigned a unique ID (gid) by the server. Since a GPS file refers to a route, the gid can be used to distinguish between routes. Finally, the data from the GPS file, the gid, and the token are inserted into the database.

2) Filter Routes: The process of filtering routes is divided into three steps. First, after road inspectors select the road segments and time period on the website, the website will send a filtering request to the server. The routes which meet the above requirements will be picked. Second, for the picked routes, the travel distance of the selected road segment is taken into consideration. The length of a road segment is approximately 1000 meters in general. Thus, only the routes with the road segment whose distance is greater than 300 meters will be selected. Third, the visibility of the street video is important since the road inspectors need to examine roads and road facilities carefully. If the traffic jam takes place, the vehicles will be hard to record the condition of the road surfaces. The speed of the vehicle is used to determine whether the traffic jam occurs or not. If the route includes more than 70% of time of which the driving speed is less than 30 km/hr, the route will not be chosen. Finally, the remaining routes are candidate routes for the inspection.

3) Send Video Upload Request: Based on the GPS-related data of the routes which build the target paths, the corresponding tokens and video file names for each route can be acquired from the database using the gid. The smartphones that own the videos can be found using the token. The back-end server sends the notifications to ask for uploading the needed video files. Thus, when the drivers receive the push notification on their own smartphones, they will know that the specified videos need to be transmitted to the server.

4) Check and Edit Videos: The back-end server periodically checks whether any video file exists in the file system or not. If the videos which are required for certain the target path have been uploaded, the back-end server will edit videos to generate the target video according to the data of the target path. Video editing is divided into two cases. The data of the target path only contains a single gid value. It represents that the target path can be built by a single route (i.e., the target video can be obtained from a single video). In this case, the target video is able to be created by cutting a single video. In the other case, the data of the target path contain multiple gid values. It means that the target path is composed of multiple routes and the target video needs to be obtained from multiple videos. Each video may need to be cut. After each video is cut properly, the trimmed video clips will be merged into the target video. Once the target video is created, the road inspectors can watch the video to check the road condition.

E. Database

The data required for the computation of the back-end server is stored in the database. The database of the developed system is composed of five tables. The first table keeps the information of the smartphones that use the mobile application. In this table, the attribute “Token” represents the registration ID which the smartphone is assigned to. The second table stores the GPS data written in the uploaded GPS file. Each tuple corresponds to a piece of GPS data. The attribute “gid” is defined for each traversed route. If the tuples belong to the same route, they have the same gid. The results of the analysis of routes are stored in the third table, including the corresponding video file names, the sequence of roads, the driving distance, and the time period. The fourth table records the districts and roads in the city. This table is used for the filtering mechanism. Similar to the second table, the fifth table stores the data of the target paths. Each target path may be composed by a single or multiple routes. Thus, the tuples with the same “vid” (vehicle ID) might have multiple gids.

4. Road Identification

After the GPS data are received, the server will analyze the coordinates to examine the roads that the vehicle has traveled. The algorithm for the road identification is shown in Fig. 2. The algorithm first check the number of coordinates of the GPS. The mobile application records its coordinates every three seconds. If the number of the coordinates is small, it implies that the travel distance is not long. Based on our

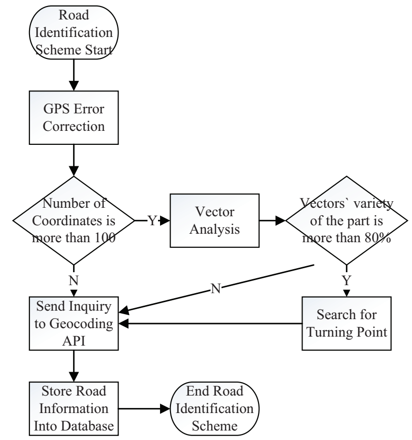


Fig. 2: Flowchart of road identification.

experiments, when the number of coordinates is less than 100, the corresponding journey typically covers one or two streets and it is easy to identify the roads. If the number of coordinates is more than 100, the algorithm will divide the GPS record into parts. Each part contains at least 100 records, and the algorithm computes the vector’s similarity for each part. If the similarity is less than 80%, the algorithm will scan the part to search for the turning point. Due to the GPS errors, the turning point may not be the intersection of roads sometimes (see Fig. 3). To locate the turning point accurately, the vector analysis is developed and described as follows.

The algorithm computes the difference of the latitude and longitude between two neighboring coordinates to obtain the vector of the vehicle’s driving direction. The algorithm scans the whole GPS track and computes its radian by setting the East as zero degree. The algorithm then records the first vector as a reference point to detect the change of the subsequent vectors. It is not accurate enough only using one reference point, so the vectors’ average direction is also utilized as an aid standard. During the scan, if the difference between the new coordinate and the standards is larger than 45 degrees, the algorithm will take the new coordinate as a pre-turning point. A threshold of pre-turning times is used for reducing the influence by GPS errors. When the pre-turning continuous occurs more than the threshold, the algorithm will consider a turn occurred and will check if the road changing really happens. A request is sent to Geocoding API to inquire the road information of the turning position. If the returned result is different from the original road information, it implies that the vehicle has driven on another road; if the result is the same, the request with the next coordinates will be sent. The inquiring will not stop until the difference is confirmed or the driving reaches a certain distance. Once the road changing is detected, the algorithm will record the street name and the position and then reset the two reference points to adapt the current road environment.

In the urban area, when vehicles stop at red light, they will wait for a few moments and the GPS data are still recorded. Due to the GPS errors, the coordinates could conclude that

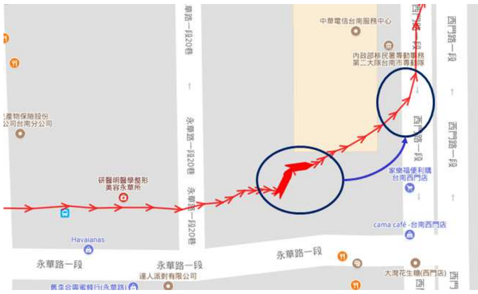


Fig. 3: Turning vector.

Fig. 4: Messy coordinates.

the vehicles were moving in a short distance with varying directions. The coordinates, called messy coordinates, are useless for the scanning process of the algorithm (see Fig. 4). Therefore, the algorithm can detect the messy coordinates and discard them.

5. Inspection Segment Creation

The inspectors input the names of roads and the website will show the available corresponding travel routes. The road inspectors click two points to decide the start point and the end point of the desired inspection. The coordinates of the two points are transmitted to the server to retrieve. Two algorithms (matching and combining) are used for searching for the required GPS data and for requesting the corresponding videos.

The grid module is implemented for reducing computation of the algorithms. Each grid is 0.0001 longitudes wide and 0.0001 latitudes long. For instance, the range of Tainan City is from 120.03503°E to 120.65626°E and from 22.8875°N to 23.412686°N. The city contains around 6000*5000 grids.

With the matching algorithm, the candidate GPS records are transformed into the grid module. The algorithm first looks for the data that are recorded on the same day and can totally meet the requirement of the inspectors. If there is no single video that can fulfill the request, the algorithm starts to divide the GPS records into three groups. The first group is the GPS records that fit the start point; the second group is the GPS records that fit the end point; the last group is the GPS records that do not have any intersection with the request. The matching algorithm then analyzes each combination of the first group and the second group GPS records to build a combination that could satisfy the requirement. If the combination is available, the information will be used for editing the target video; if no match data could be found, the “not found” will be returned.

Each GPS record is stored in the chronological order and has been put into the Grid Module. The combining algorithm

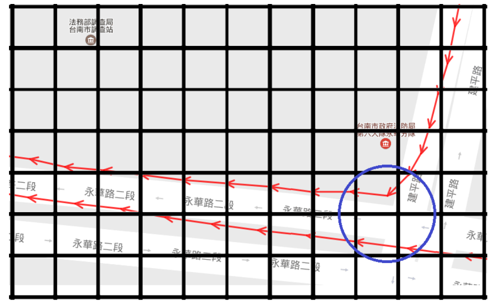


Fig. 5: An example of GPS error in grid.

checks whether there exist one or more contact grids in the GPS records. If yes, the GPS records can be merged to a new route; if not, they cannot be combined. The combining algorithm does not work well due to the GPS errors. As illustrated in Fig. 5, two travel routes meet each other at the road intersection, but the grids are separated because of the GPS error. To prevent this situation, the algorithm does not only check the current grid, but other five grids with its own direction, including forward, forward-right, forward-left, right, and left. Once the combining algorithm detects there are offset coordinates that can connect two GPS records, it will store the coordinates into the database for editing the video.

6. Implementation

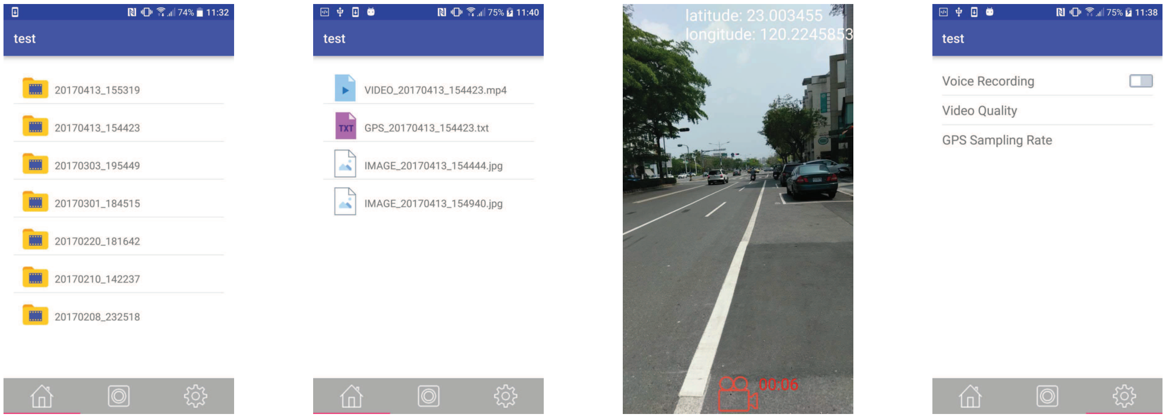
The mobile application is implemented on the Android System. The user interface of the mobile application is illustrated in Figure 6. The developed android application records videos in MP4 format. During the video recording, the GPS-related data are collected and stored in a text file. In order to send video upload notifications to the smartphones, Firebase Cloud Messaging (FCM) is used with the mobile application. The FCM is a service provided by Google [14].

The website is implemented with HTML, JavaScript, and CSS. The website contains two web pages and each of them is embedded with a Google Map. For integrating Google Maps with the web pages, Google Maps JavaScript API is utilized [15]. As mentioned previously, the road inspectors can choose the desired roads and watch the corresponding video on the website. The implementations include obtaining coordinates, showing routes on the map, filtering routes, playing videos, and displaying photos on the map, respectively.

In order to execute the matching algorithm, the back-end server must obtain the coordinates of the origin and the destination of the target path. Markers provided in the Google Maps JavaScript API are used to acquire the coordinates of the origin and the destination. A marker can be added via clicking on the map, and its coordinates are able to be retrieved.

The road inspectors should be able to identify the road segments which have been traveled as well as the target paths easily and clearly. The routes on the map are drawn with arrow symbols to show the directions of the routes by employing the PolyLine class in the Google Maps JavaScript API.

When there are many routes in the route list, the road inspectors might spend a lot of time looking for the needed routes. Therefore, a form is designed to filter the routes. The



(a) Folder page. (b) File page. (c) Video recording page. (d) Setting page.

Fig. 6: User interface of mobile application.

form has a dependent drop-down list with an auto-complete feature and three buttons. After the target video is generated, it will be appended to the video list on the inspection page. If the checkbox is checked, the corresponding target path will be drawn on the map. The road inspector clicks the "WATCH" button to play the video.

Based on the value of the photo flag stored in the GPS table, the GPS data with the captured photos can be identified. When the marker on the map is clicked, the photo will be presented on the window. The abnormal events that are reported by drivers can be examined.

The back-end server is implemented with Apache. The tasks which are performed by the back-end server are implemented by PHP. The database is developed by MySQL 5.7.14. Numerous database instructions are provided for the back-end server to access the data in the database.

The performance of the road identification is evaluated. 20 routes with a total of 61 roads were tested. Compared to the data with the real driving condition, the accuracy of turning points and road identification reached almost 90%. The cases that the system cannot identify correctly are typically special road environments.

7. Summary

Regular road inspection is a vital part of road maintenance. Current approaches to the road inspection typically require a lot of labor, time, and expenses. This paper proposed that the load of the road inspection could be distributed to ordinary drivers. An auxiliary system for the road inspection based on geotagged videos and map services was developed. The drivers use the developed android application to record videos and to obtain the GPS data when they are driving. The collected GPS data are transmitted to the server for analysis. The traveled road segments can be identified and be displayed on the map of the website. The road inspectors choose the paths which they are scheduled to examine, and the corresponding videos will uploaded from the drivers' smartphones. Therefore, the inspectors can assess the preliminary condition of the rodes without traveling. With the system, the road inspection tasks will be executed more efficiently. The whole system was implemented and tested successfully in Tainan city area. The system can capture the driving routes and generate the inspection videos correctly.

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