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An Approach to Produce a GIS Database for Road Surface Monitoring

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Abstract

Road Surface Monitoring (RSM) is the process of detecting the distress on paved or unpaved road surfaces. The primary aim of this process is to detect any distress (such as road surface cracks) at early stages in order to apply maintenance on time. Early detection of road cracks can assist maintenance before the repair costs becomes too high. Local authorities should have an effective and easy to use monitoring process in place across the road network to meet their obligations.
The process of adding geographical identification metadata to the photos is called "Geo-tagging". The proposed method in this work entails capturing GPS information when the photo is taken for the road surface distress, then attaching the photo to a map. The location disclosure in the act of geo-tagging of a photo provides qualities to the digital map. In that respect, a specific richness of the GIS dataset arises when they disclose the road surface distress photos.
This paper proposes a system for establishing a GIS database consisting of geo-tagged photos for local authorities to automate the process of recording and reporting road surface distresses. This system is easy to use, cost-effective, deployable, and can be used effectively by local authorities.

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1. Introduction

Road Surface Monitoring (RSM) is the process of detecting the distress on paved or unpaved road surfaces.

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The primary aim of this process is to detect any distress (such as road surface cracks) at early stages in order to apply maintenance on time. Early detection of road surface cracks can assist maintenance before the repair costs become too high. In addition, measuring the condition and performance of roads are continuously developed overtime with the new methods and improvements. Recently, many researchers have proposed efficient collection of pavement condition data. Significant progress in this field has been made, and new approaches have been proposed such as [1]. The acquisition technique using images is more cost effective, easier, more dense (each millimeter), and more precise in measuring the defect. There are many image acquisition techniques are available [2]-[7].

Images from consumer cameras on different platforms such as Unmanned Aerial Vehicles (UAVs) or terrestrial based mobile system can be cost effective compared to satellite's imagery or traditional aerial photography [7]. Satellite images can be another source for monitoring road distress. However, due to the cost and the limited spatial resolution quality of the image, it is not preferred.

The detection and measurement of the pavement cracking provides valuable information to the local authorities on the road network condition and reduces maintenance costs. Significant progress has been made in recent years in using a variety of techniques for assessing the pavement road surface. For efficient collection of pavement condition data, different approaches have been proposed, and various automated systems have been developed world widely since the 1980s. Previous approaches to pavement condition involved a labor-intensive, time consuming, and risky process of data collection [8]. A quick, easy to use, and cost-effective method for establishing a GIS database is proposed in this paper.

2. Data collection

The information about the road distresses are collected in Nottingham city – UK. Nottingham is located in the heart of England. The city's excellent transport system links make it the ideal location from which to explore. Due to its variety of public transport and cycling routes, Nottingham has been named as the least car dependent city in the UK [9]. The area of the city is approximately 28.8 square miles (74.6 km^2).

The data on the street distress sites are collected wherever they are noticed. Several areas within the city are visited by bicycle and data about the type, severity level, geographic location, dimensions, and photos of the distress are recorded. The location of 50 street distresses has been noticed and the relevant data were recorded. Each point is uniquely labeled with alphanumeric names as P*xx*; where *xx* represents the positive two-digit integer values.

Any low-cost hand-held GPS can be used in this type of projects. The geographic location (Latitude, Longitude, and Elevation) for each point is recorded using Topcon GMS-2 receiver. The GMS-2 receiver is a single-frequency, GPS receiver and hand-held controller built to be compact and portable receiver for the GIS surveying market [10]. According to Nisanci [11], GMS-2 receiver provides the functionality, accuracy, availability, and integrity needed for fast and easy data collection. However, the GPS has some restrictions and the choice of each point is selected such that the equipment is exposed to various error sources. For example, GPS signals may be reflected from the neighboring water strip and the angle of clearance to satellites is obstructed by the tree canopy. In addition, the inconsistent GPS readings may be caused by signal multipath from nearby buildings and/or bad satellite geometry, which reduce the accuracy.

The dimension of each distress is measured by tape at each severity level. If different severity levels exist, the entire distress is rated at the highest severity.

Cameras are considered the most crucial part in photogrammetric projects. In the road maintenance and crack detection, the camera has to be strong enough to detect the crack on the surface. A camera with a good photography is the function of some parameters such as: field of view, exposure, and pixel size. The 7.2 megapixel Sony P200 Cyber-shot personal digital camera is used to snap the photos of each distress.

3. Geo-tagging

The geographical identification metadata, such as latitude and longitude, is added to every photo taken for each point.

The P200 Sony digital camera does not contain a built-in GPS receiver. Therefore, a hand-held GPS receiver is used with a non-GPS digital camera for geo-tagging. Alternatively, time synchronization may be performed in which the timestamps made by the camera clock is compared with the timestamps in the recorded GPS information. The resulting coordinates can then be added to the metadata of the photo file (Exchangeable Image File Format (EXIF)) which has standard tags for location information.

Road distress photos are taken first without geographical information and is processed later using a dialogue box ‘Edit Data’ in GeoSetter software version 3.4.16 in conjunction with the GPS data. These photos are saved to a folder and clicked each individually to call up its metadata.

GeoSetter is a free tool for editing digital image metadata, but with a special emphasis on geographical data. It includes a Google Map feature that shows where the picture was taken. In addition, EXIF and other image data can be also edited. To change the data of an image, this image should be selected in the main window of GeoSetter. Providing new or changing corresponding data can be performed in separate window tabs. The changed data are saved in the file EXIF. Software interface with the relevant road distress locations in Nottingham is shown in Fig. 1.

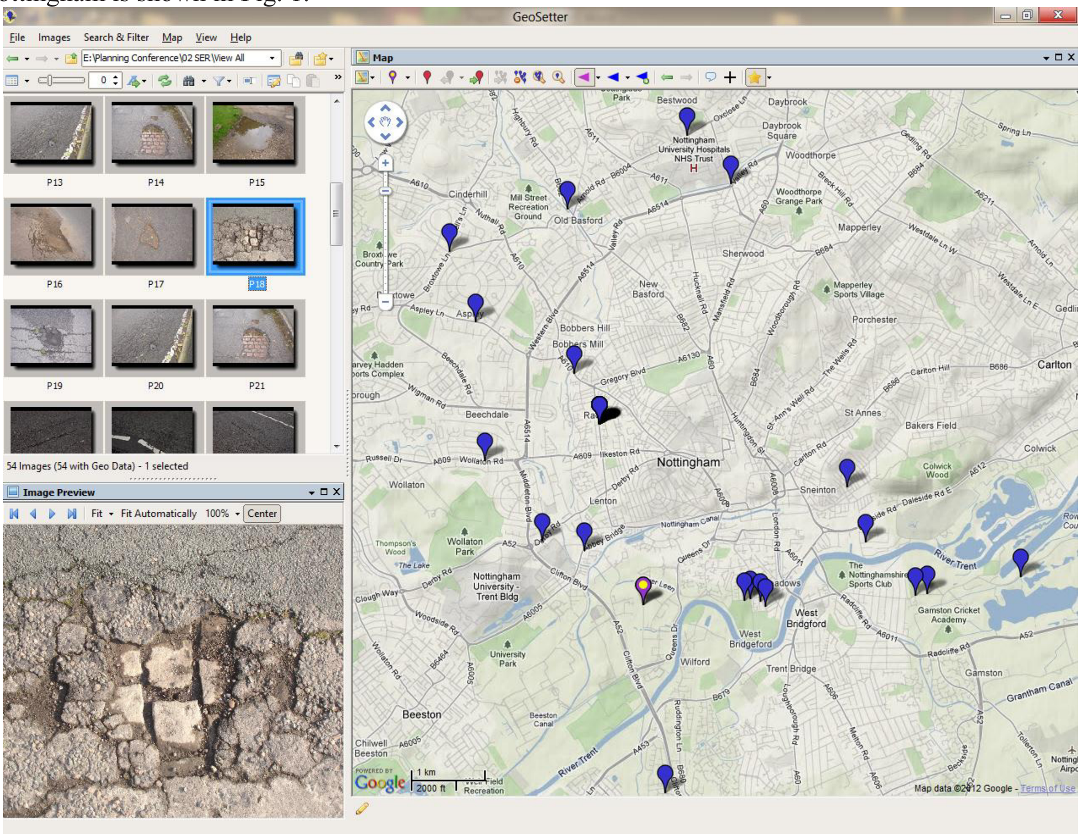

Fig. 1. Road distress locations on the digital map

GeoSetter's simple interface is divided into two halves. On the left, there are file browser and image preview panes, and on the right is an embedded Google Map that allows viewing geo-tagged images as graphics on the GIS map. The program also opens with an extensive settings page, with 10 tabs for configuring File Options, Camera, Start-up, ExifTool, and more.

Geo-tagging is considered as an organizational tool that allows visualizing the exact location where the photo is taken on a map. It also allows (if photos are shared online) to search for photos taken on or nearby a particular location. In addition, it is possible to track a route on a specific date and may improve the future plans of local authorities in handling and repairing the road pavement distresses.

4. Establishing database for GIS

The classification and quantification of the type, severity, and amount of surface distress is a primary method for assessing the condition of road surface pavements. The type, severity and quantity of the distresses along any road can be saved in a database. In this regard, road pavement distresses in a GIS database become a physical record documenting both the quantity, and the location of the distresses.

When a road is inspected, the pavement engineers and technicians working with local authorities review the database by searching the road photos. A wide range of information can be created or extracted from the geo-tagged image graphic by clicking on the image. Then, the technical staff will accordingly verify or update the severity of the existing distresses that have not been repaired, remove previous distresses that have been repaired, or add new distresses that have been identified.

This process eliminates the continuous re-measurement of the same road pavement distresses at each update and significantly reduces the cost to re-inspect the road network in subsequent years. The key to this process is the ability to easily correlate the road distress image to the position on the ground shown on the digital map. For example, in this work, the road pavement distress is classified into low, moderate, and high. Each severity type is defined as:

- Low: An area of cracks with no or only few connecting cracks; cracks are not spall or sealed.
- Moderate: An area of interconnected cracks forming a complete pattern; cracks may be slightly spall.
- High: An area of moderately or severely spall interconnected cracks forming a complete pattern; pieces may move when subjected to traffic.

In addition, the type of distresses in this database is classified as: 1) Cracking Distresses; 2) Patch Distresses; 3) Potholes Distresses; 4) Rutting Distresses; and 5) Shoving Distresses. Different types of road distress types are shown in Fig. 2.

Fig. 2. Different Examples of Road Distress Types: (a) Pothole Distress; (b) Cracking Distress

The location disclosure in the act of geo-tagging of a photo provides qualities the GIS map. In addition, it adds information on its location and also an act of communication containing what engineers and technicians can estimate. In that respect, a specific richness of the GIS dataset arises when they disclose the road surface distress photos.

GIS databases have the capacity to stimulate inter organizational cooperation and collaboration and are expected to result in the provision of a better information base for management and strategic decision making in RSM. Avoiding unnecessary data duplication and redundancy of efforts is one of the most important goals of data coordination initiatives.

The data in this work are shared via Google Drive which gives the users 5GB of free data storage in the cloud. With Google Drive, the data are shared with others in real time on any computer file format. Once content is chosen to be shared with others, it is possible to add and reply to comments on anything (PDF, images, maps, documents…etc.) and receive notifications when other people comment or change the shared items. In addition, the data are stored safely and they are accessible anywhere and anytime. Furthermore, any piece of information in the database is searchable.

5. Conclusion

A quick and cost-effective method is proposed in this work to establish a database for GIS for road surface monitoring purposes. This work can be performed by one person (one-man job). The whole process of circling the city for road pavement distresses, taking photos, coordinates measurements, geo-tagging, and establishing a database for 50 points was less than two working days and without any prior knowledge about the distress locations. Much more points can be established in the database providing that the road pavement distress points are known or reported in advance by the local authorities.

In this work, two devices are used in the field, the camera and the GPS. Recent digital cameras with built-in GPS receivers are not commonly used, although some high-end cameras are already equipped. Unfortunately, the majority digital camera manufacturers are not keeping up with technology on this field. This is either because including a GPS device would make the camera more expensive or because geo-tagging is still not a mainstream life requirement. However, mobile smartphones are used extensively around the world. Most of the smartphones integrate GPS receivers and cameras, which can be used auto geo-tagging, although an appropriate application may be required if this ability does not already included.

Although most GPS receivers, such as Topcon GMS-2, are very accurate, they encounter some errors. Multipath and unavailable clear view to the satellites in urban environments degrade the accuracy and integrity of GPS ranging and affect satellite geometry with respect to receivers that operate in dense urban areas.

This method has significant benefits and proven performance using an easy and cost-effective technique in road surface monitoring. This method reduces the training required to process field data for use in expensive professional GIS software. In addition, this method increases productivity by streamlining workflows when collecting field data and GPS data or working with geo-tagged road distress photos and processing these data in a geospatial context. The method used fast and flexible interface to create a database from the field collected data, including geo-tagged photos. Further, the method offered flexible data collection options in which only a hand-held GPS receiver and digital camera are used in the field. No personal computer or cable connections were required.

The future work may include more than one photo is taken for distress. This is because typical mapping platforms require users to select a common point in two or more images to triangulate and establish a coordinate position on the ground for further analyzing and quantifying the distress in an engineering manner.

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