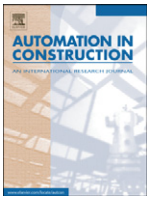
Automation in Construction 53 (2015) 95–104

Contents lists available at ScienceDirect

Automation in Construction

journal homepage: www.elsevier.com/locate/autcon



Patch detection for pavement assessment

Stefania C. Radopoulou [a],*, Ioannis Brilakis [b]

[a] Division of Civil Engineering, Department of Engineering, University of Cambridge, ISG62, Trumpington Street, Cambridge CB2 1PZ, UK
[b] Department of Engineering, University of Cambridge, BC2-07, Trumpington Street, Cambridge CB2 1PZ, UK

ARTICLE INFO

Article history:
Received 22 July 2014
Received in revised form 27 February 2015
Accepted 5 March 2015
Available online 21 March 2015

Keywords:
Patch
Detection
Pavement assessment
Pavement defect
Automatic detection
Image processing

ABSTRACT

Pavement management systems rely on comprehensive up-to-date road condition data to provide effective decision support for short, medium and long term maintenance scheduling. However, the cost per mile of the existing condition data collection methods allows only for periodical surveys. This leads to long gaps between inspections and a focus on major roads over rural ones. Therefore, pavement condition monitoring systems that provide inexpensive frequent updates on the road condition are necessary. Such systems would require robust and automatic defect detection methods using low-cost sensors. In this paper, one such method is proposed for detecting road patches from video data acquired by the car's parking camera. A patch is initially detected based on its visual characteristics, which are: 1) it consists of a closed contour and 2) its texture is the same with the surrounding intact pavement. The patch is then passed to a kernel tracker in order to trace it in subsequent video frames. This way redetection is avoided and each patch is reported only once. The method was implemented in a C# prototype and tested with video data consisting of approximately 4000 frames collected from roads in Cambridge, UK. The results show that the suggested method has 84% precision and 96% recall.

© 2015 Elsevier B.V. All rights reserved.

1. Introduction

The National Academy of Engineering has identified “Restoring and improving urban infrastructure” as one of the Grand Challenges of Engineering in the 21st century [1]. The report emphasizes the problem of maintaining infrastructure in which streets and highways are critical transportation conduits. According to the World Bank, roads often carry more than 80% of passenger-km and over 50% of freight ton-km in a country [2]. Roads assist mobility, enable growth and contribute to economic prosperity, productivity and well-being [3].

Many reports/articles that discuss the condition of the current road network and highlight the significance of efficient road maintenance have been issued. For example, in the US roads are characterized as being in poor condition and action is necessary for improvement [4]. In the UK, 61% of the country's business leaders rate local transport networks poorly in comparison to international benchmarks, while 50% of firms believe that network conditions have deteriorated over the past five years [5]. Additionally, 43% of the UK residents rank road and pavement repair to be the second highest priority for improvement [6].

Councils in the UK invest in maintaining the road condition by splitting the allocated funds spent on local roads to 75% for maintenance and 25% for construction [6]. The former share equals to 2.3 billion pounds, and constitutes a 73% increase in cash terms since 2000. Highway infrastructure assets require attention due to their great value to the public sector [7]. The concept of asset management has resulted in savings of up to 15% in some sectors. In the case of highways, it has been reported that savings of at least 5% on budget expenses have been noted. According to the International Infrastructure Maintenance Manual (IIMM), the first requirement for an impelling asset management system is to have knowledge of the existing assets, the status of their condition and the level of service they provide [8]. Pavement condition assessment data is essential when designing, planning and choosing the appropriate road maintenance programs.

The current process for assessing pavement condition comprises of the following steps: 1) collection of raw data, 2) identification of defects and 3) defect assessment. The first step is to a large extent automated; however, the other two are mostly performed manually. With regard to pavement defects, the UK Pavement Management System (UKPMS is the national standard for management systems that assesses the condition of the local road network and plans the investment and maintenance of paved areas of roads) user manual identifies the most important and basic types as cracks (longitudinal, transverse, alligator), potholes, patches, rutting and depressions [9]. The former three can be classified as *surface defects* and the rest as *elevation defects*.

Nowadays, the most effective approach for inspecting the road network is with the use of dedicated vehicles. Accredited inspectors travel in specialized vehicles for collecting raw data in different forms with the aid of several sensors, such as laser scanners, road profilers, accelerometers, image and video cameras and positioning systems [10–15]. Laser scanners, which have a resolution of thousands of points, are used to measure the longitudinal and transverse road profiles. The output is a 2D depiction of the road (either along or perpendicular to the path of way) showing the difference in the elevation along with the chainage

---

* Corresponding author.

E-mail addresses: scr58@cam.ac.uk (S.C. Radopoulou), ib340@cam.ac.uk (I. Brilakis).

http://dx.doi.org/10.1016/j.autcon.2015.03.010
0926-5805/© 2015 Elsevier B.V. All rights reserved.

[12,16]. Image and video cameras, positioned either at the front or at the back of the vehicle, are used to capture the condition of the road visually and provide inspectors with image data [13,15,17].

Such vehicles are very expensive to purchase as well as to operate. The Transport Research Laboratory (TRL) in Great Britain reports prices starting from £500,000, with the cost of operation and data processing ranging from £20 to £40 per kilometer [18]. Their main advantage is that they can travel at highway speeds (up to 100 km/h) without disrupting traffic, while collecting data. However, their prohibitive purchase and operational costs lead several western countries and US states to afford just a few of them. Hence, their application is limited to the principal road network, which in the UK it only constitutes 9.6% of the country's entire network [19]. This limitation also leads to large time intervals between inspections [20] leaving the rest of the network subject to more traditional, time consuming and laborious manual survey methods [11,13]. To the knowledge of the authors, no statistics are published with regard to the specific times/man hours spent for data collection. However the difference between the two available methods is easy to understand considering that manual surveys are performed on foot [9].

The next step in the process of pavement condition assessment is the analysis of the collected data. At this stage, the pavement profiles are further processed either to produce specific parameters that will assist in the calculation of the Road Condition Indicator (RCI) [11] or to calculate the pavement roughness, which is specified by an International Roughness Index (IRI) [21]. In detail, the road is split into chunks of different lengths and the corresponding collected data is processed and collated to measure the aforementioned parameters and produce a general characterization of the specific road. This aims at realizing whether this part of the road needs further detailed investigation or not [11,13]. The digital pavement video data are manually viewed and analyzed by technicians on workstations. They visually detect and assess defects based on their own experience and guided by a manual for defects, while sitting in front of two or more monitors [21,22]. The units of measure used are meters, millimeters, square meters and number of occurrences depending on the kind of defect [22].

Although the defect evaluation is performed following well-defined guidelines and criteria, it is laborious and inevitably introduces a certain amount of subjectivity. This is of paramount importance for the outcome of the results [13,23]. Unfortunately, inspectors' level of experience is expected to influence the pavement rating [24]. Private companies provide software that can assist the above process. However, such software is complementary to the equipment that the companies provide and are not provided as stand-alone packages [12,14]. Moreover, this adds to the cost of using this approach. Specific prices are not publicly available unless interest of purchase is expressed. However it is reasonable to assume that they are expensive.

With regard to the software and the algorithms themselves, little detailed information is disclosed. In general though, the data collected from the equipment mounted on the specialized vehicles (3D laser scanners, image and video cameras, etc.) are post-processed to either provide results for all defects simultaneously or individually [12,14]. Great emphasis is given to the analysis of cracks, but other defects can also be detected with such software. However, these systems fall in the category of specialized vehicles that are very expensive to purchase and operate.

In summary the issues currently identified in the pavement condition assessment process are twofold. A vast amount of data is collected and either post-processed manually leading to great time and money consumption or analyzed with expensive software, which requires the use of specialized vehicles for the data collection. Therefore, in this paper the focus is on proposing a method that is free of such limitations. In the following section, the current state of research related in automated patch detection is presented. In addition, methods useful to the research objective are also discussed. Then, the proposed solution of detecting and tracking patches is analyzed that is using data acquired from the parking camera of the car, in order to utilize a pre-existing sensor and avoid additional costs. Such cameras usually have a resolution between 0.2 and 0.4 MP; their cost ranges from £30 to £100 and can be simulated with a machine vision camera of the same characteristics that costs around £195. The paper continues with a presentation and discussion of the experiments performed to validate the proposed method and the results obtained. The final section of the paper presents the conclusions and future work.

2. Background

Much research has been performed for overcoming the limitations of current practices and automating pavement defect detection. Extensive research has been done with respect to the defect of cracks. More specifically, methods that perform crack detection [25–33], real-time crack analysis [34–37], crack classification [32,38–42], crack depth estimation [43] and even automated crack sealing [44,45] have been proposed. Detection of other surface defects such as patching, potholes and raveling in 2D images has also been investigated. For potholes, a method that detects them in images amongst cracks [46] utilizing the characteristic of texture to distinguish each defect has been presented. Another method aiming at detecting potholes [47], tracking them in videos [48] and measuring their properties [49] has also been proposed.

For patches, a couple of methods have been found in the literature. However, these methods present several limitations. At this point, the difference between presence and detection should be noted. Presence refers to the result of a process when this is only capable of providing a yes or no answer to the question of whether an object exists in the data. Detection provides the additional information of where an object is located within the given data. Hence, some methods are restricted to only recognizing the presence of a defect and classifying images between intact and healthy pavement without specifying the defect type nor which part of the image they occupy [50]. Others that use image thresholding techniques are not capable of distinguishing patches from potholes [51–53]. Finally, a statistical second order method found in the literature detects patches, but is limited to doing so in concrete pavement images [54].

From the abovementioned methods, some [33,46] use techniques from the fields of machine learning and data mining, such as Support Vector Machines (SVM) and Artificial Neural Networks (ANN). Those fields include algorithms that aim at identifying objects by learning from data. In other words, data is used to make the algorithms “learn” a specific pattern and create a “model”/rule which will then be used for the identification of the desired object. The main benefit provided is that such algorithms remove the burden of creating the detection model from the designer. On the other hand, a lot of data is required for “learning”. Therefore, if a manual model is able to detect the object robustly, there is no need of finding data for the “learning” process. Hence, the authors decided to explore the option of creating a manual model knowing that if it fails, machine learning will be investigated.

The framework of Visual Pattern Recognition (VPR) models has been proposed for creating models to automate the detection of infrastructure-related objects [55]. The idea behind this framework is to create unique detection models by utilizing their distinctive characteristics, such as metric measurements, and geometric properties. Such models have successfully been created for the detection of air pockets in concrete structures [56], concrete columns [57] and potholes [47,49]. Amongst the features used for creating VPR models is texture.

In general, there are three major approaches of describing the texture of a region and those are structural, spectral and statistical. Structural approaches are ideal for describing textures that are characterized by image primitives like parallel lines. Spectral approaches are mainly used along with Fourier transforms for detecting high energy and narrow peaks of the spectrum. Statistical approaches are most suitable for describing smoothness, coarseness, granularity etc. of the texture [58,59].

Download English Version:

https://daneshyari.com/en/article/246358

Download Persian Version:

https://daneshyari.com/article/246358

Daneshyari.com