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Automated detection of faults in wastewater pipes from CCTV footage by using Random Forests

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Abstract

Sewer systems require regular inspection in order to ensure their satisfactory condition. As most sewer networks consist of pipes too small for engineers to traverse, CCTV footage is used to record the interior of these pipes. This footage is manually analysed by qualified engineers, to determine the condition of the pipe and the presence of any faults. We propose a methodology, which automatically detects faults within the CCTV footage. This has the potential to dramatically reduce the time required to process the large volume of CCTV footage produced during a survey. The proposed methodology first characterises localised regions of each video frame using multiscale GIST features. Extremely randomised trees are then used to learn a classifier that distinguishes between frames showing a fault and normal frames. The technique is tested on 670 video segments from real sewer inspections of a variety of pipes, supplied by Wessex Water. Detection performance is assessed by plotting receiver operating characteristics and quantifying the area under the curve. Preliminary results indicate high detection accuracy of 88% and an area under the ROC curve of 96%. The machine learning used reduces the footage to a selection of frames containing faults, which can be quickly identified (whether by an engineer or another piece of software), showing promise for use in industrial wastewater network surveys.

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1. Introduction

Wastewater networks around the world require regular inspection in order to prioritise and perform effective maintenance. Currently wastewater networks are inspected using CCTV, taking one of two approaches. The first requires a camera, attached to a semi-rigid wire, to be pushed through the network. In doing so the collected footage is left to be analysed later by a trained engineer. Although quick to collect, the footage gathered is often of lower quality as the camera does not travel smoothly through the pipe. Alternatively a camera can be attached to a remote controlled PIG (pipe inspection gadget) which is driven through the network. Due to the live feed and superior control provided by the PIG, a skilled operator can often identify and record faults whilst operating the device. In doing so footage takes longer to collect, but does not require further analysis and is often of higher quality.

Both approaches are expensive, requiring a trained engineer for the duration of the survey and the follow-on analyses. Collecting footage using a wire is cheap, although the later analysis is slow and expensive, whilst using a PIG is slow and expensive, especially as PIG operation requires additional training. Additionally, both methods rely on the training and experience of the operator/analyst, even given a formal guideline [1], operators are only human. It is not uncommon for a single fault to be classified incorrectly or overlooked, due to the subjective nature of most faults [2].

The proposed methodology attempts to counter the problems identified above. The method aims to classify frames of CCTV footage into faulty and normal categories, which can be further categorised by an engineer. By doing so the methodology attempts to reduce days and hours of footage down to a selection of relevant frames, most of which contain only faults. It is hoped that this will in turn reduce the costs (both time and money) associated with surveys, whilst preserving (or improving) a survey's accuracy.

2. Background

A limited amount of work has been previously undertaken in this field, most notably by Duran et al [3] and Sinha et al [4]. Duran chose to retrofit the traditional CCTV camera with a laser profiler, in order to get accurate information about the pipe's interior. Passing the profiler's readings through a series of ANNs (artificial neural networks), Duran was able to accurately (90% +) classify a selection of faults fabricated in a laboratory. On the other hand, Sinha applied fuzzy logic to the problem, identifying five characteristics, which could be reasonably measured and were key to detecting a fault. These were light intensity, texture, size (major and minor axis lengths), shape and organisation. The features, once fuzzified, were again passed to an ANN classifier, and produced accuracies of 85-95%, for joints, cracks and connections on flush cleaned concrete pipes.

Neither of these approaches was demonstrated using raw footage from real CCTV surveys Duran's methodology was only tested in laboratory-based, fabricated experiments, whilst Sinha's methodology was tested on flush cleaned pipes. This leaves both methodologies untested in a 'real world' environment, and their usefulness to industry unproven. Furthermore, both Duran and Sinha choose to use ANNs (Artificial Neural Networks), a black box approach to classification. In opting to do so, information about a classification is lost, providing little justification for each decision. This lack of understanding and accountability makes it harder to justify detections and classifications made by Duran and Sinha's methodologies.

3. Fault Detection Methodology

Acknowledging previous work in the field, this methodology aims to work from actual survey data, in order to ensure its applicability to 'real life' systems. The methodology was developed on footage taken from actual surveys undertaken by the Wessex Water, collected using both wire driven cameras and PIGs. This footage was processed, before being classified by a trained random forest in order to identify whether individual frames contained faults. In order to prepare the random forest, a separate library of processed frames was labelled. The labelled frames were