IntelliBike: a cycle path surface quality assessment tool

Mr James C. Calvey

Research Student

Edinburgh Napier University

Dr Mark D. Taylor

Lecturer in Civil Engineering

Edinburgh Napier University

Dr John P. Shackleton

Lecturer in Product Design

Edinburgh Napier University

Mr Richard Llewellyn

Lecturer in Civil Engineering

Edinburgh Napier University

Abstract

The IntelliBike is an instrumented bicycle capable of monitoring cycle path surface quality through onboard measuring and logging devices, as well as other key variables pertinent to infrastructure and environmental quality and thus cyclist comfort. Research methods, results, and equipment adopted are presented. The bike is fitted with a Madge Tech Shock 101 Vibration logger, two onboard video cameras, and a net-book for real-time software analysis and a collection of other data gathering equipment such as a light meter, sound meter, and bicycle computer. A cycle path's running surface must be kept to a high standard as defects can cause a potential hazard to path users. A single path can be comfortable to one person and uncomfortable for the next, so differentiating path quality so that money is appropriately spent is a high priority for councils. While being cycled, humps, bumps, and excitations are constantly logged to the IntelliBike's onboard vibration data logger and a custom designed rating system breaks down these vibration levels into a five point quality ranking scale. In this paper, the survey conducted in order to design the rating system is discussed. A stratified sample of cyclists was chosen to cycle a path in which they gave their opinion as to the quality and comfort of the path; the results yielded formed the basis of the development of the overall rating system. A wide selection of users ranging from experienced club cyclists to complete novices was chosen so as to have the broadest opinion. A dedicated software platform will be used to collate these data linking the vibration data with the onboard camera footage, and geographical location, the presentation process will provide an asset management tool aimed at better targeted cycle path surface maintenance.

Introduction

The vibration levels experienced by a cyclist are the most important factor that influences overall cyclist comfort when cycling along a road or off-road path. As surface quality and type directly influence vibration levels the surface is an important factor a designer will have to consider when designing a path, this is the part of the path that directly comes into contact with the bicycle and thus the cyclist, if the surface is poor it will be uncomfortable to cycle on so ideally the path will be smooth, surface type also affect the attractiveness of the path, and the costs involved in maintaining them, designers need to choose a surface type suitable for the route in question, the expected use and budget will affect the final choice, routes that are expected to be used heavily will benefit from a bound solid surface. Surfaces can suffer from a number of defects, such as potholes, weathering, rutting, root damage, and cracking to name but a few, these effects can have hazardous results on a cyclist. As travelling with greater speed increases vibration levels when cycling over a defect possible damage to the cyclist and bicycle can occur because of a hazard.

When cycling there are many resistances the rider must overcome in order to be able to cycle forward, the point of pedalling is to exert a propulsive force against the ground, to maintain speed the size of the force must be equal the total force resisting the forward motion which is composed of numerous resistances (air, slope, rolling, bump) Wilson (2004), bump and ruts etc reduce forward velocity, so lots of energy can be lost from rough and bumpy surfaces which in turn requires the cyclist to expel more energy. It is the surface resistance that is really being looked at in this paper as the IntelliBike is being designed as an asset management tool which will allow decision makers to see the current state of their off-road cycle path infrastructure.

The IntelliBike is an instrumented bicycle capable of monitoring cycle path surface quality through onboard measuring and logging devices, as well as other key variables pertinent to infrastructure and environmental quality and thus cyclist comfort. The bike is fitted with a Madge Tech Shock 101 Vibration logger which logs the excitations caused by the vibrations between the bicycle and surface, it is also fitted with two onboard video cameras, and a net-book for real-time software analysis; as well as a collection of other data gathering equipment such as a light meter, sound meter, and bicycle computer. A cycle path's running surface must be kept to a high standard as defects can cause a potential hazard to path users. A single path can be comfortable to one person and uncomfortable for the next, so differentiating path quality so that money is appropriately spent is a high priority for councils, this is where the IntelliBike will assist.

As the vibration logger only records vibration levels and does not categorise levels of quality a comfort perception study is currently being conducted with a targeted number of thirty users ranging from experienced club cyclists to complete novices, this helps give the broadest opinion. The comfort perception study will take the opinions of the thirty users as to the quality of three chosen routes and map them to the vibration logger, so when the IntelliBike is being used on off-road paths to look at surface quality a broad selection of users will have assisted in calibrating the quality levels which have been categorised. The research being conducted contributes to the development of knowledge and practice in relation to sustainable infrastructure development. Currently the UK's National Cycle Network comprises of 25,750 km of cycling and walking paths of which a large percentage is dedicated off-road infrastructure; this represents a significant civil engineering infrastructure asset that currently contributes to the provision of a sustainable transport mode option nationwide. Commuting and recreational cyclists have observed the often hazardous conditions on these paths. There are various simple, effective, measures that could be taken to improve the maintenance of such off-road paths, however, reliance on walk-over surveys and path users notifying the damage reporting sections of the relevant roads authorities is not tackling maintenance in a resource efficient manner. While these methods represent a reactive approach, the IntelliBike will be a preventative approach to management.

Previous research

Maintenance is essential so that people continue using a cycle path, potholes, ruts, and debris, can cause potential hazards to cyclists. Throughout the years different companies and institutions have designed or are designing bicycles to monitor cycle path infrastructure, all of which have similarities to the IntelliBike and at the same time differences, the IntelliBike aims to bring the ideas of what has come before and bring them together with newer ideas. The IntelliBike team has been inspired by the real world need for good quality cycling infrastructure and by other groups and companies who have worked on similar projects to different degrees of success, a study by Hölzel, Höchtl and Senner (2012) highlighted the fact that there is a demand for greater information relating to the transmitted road vibrations in cycling, with this need coupled with Cleland, Walton and Thomas (2005) stating that the effect of surface texture and the effect of objects on bicycle stability are best measured with actual cyclists riding over the objects or textured surfaces highlights the need for a device such as the IntelliBike.

The City of Copenhagen used an instrumented bicycle fitted with an accelerometer which measured accelerations caused by the surface roughness of a path Jensen and Arshadi (2007) found that the measured accelerations were dependant on the speed of the bicycle, the width of the tire, the tire pressure, and if the bicycle is fitted with any type of shock absorber, so for these reasons a constant tire pressure and bicycle speed have been followed. The data found by the accelerometer was moved from the dedicated software package to a Excel programme which analyses the data and distributes the accelerations into different quality ranges (Comfortable to unacceptable), a quality range is being developed for the IntelliBike.

The Dutch Fietsersbond conducted their Cycle Balance project back in the late 1990s and early 2000s Borgman (2003); essentially it was a benchmarking project which used multiple steps. One such step was the use of the Quick Scan Indicator for cycling infrastructure (QSIF), the tool measured and assessed cycling infrastructure in a municipality from the cyclists' perspective in a simple and reliable manner, the bicycle measured time, distance, speed, sound, and vibrations, the bicycle was linked to a computer program which processed the results, the data they were finding linked to the 5 key requirements for a cycle paths, coherence, directness, attractiveness, safety, and comfort.

Hoedl, Titze and Oja (2005) developed and tested a simple and efficient audit toll which gave them a summarised overview of the environmental characteristics along a route, their project "The Bikeability and Walkability Evaluation Table" (BiWET), looked at 15 characteristics of a street over 10 metre segments, the surveyor cycles along and stops every 10 meters and records the existence or value of each item on the survey sheet, this concept is similar to the perception study except the user is constantly logging their opinion to an onboard microphone.

Jia, Reddy and Estrin looked at road surface quality through the use of a smart-phone fitted with an accelerometer, the equipment designed and used is entirely in a smart-phone, the project falls under the category of participatory sensing, like the IntelliBike the project employs the use of maps to present the data in a user friendly manner and is also drawing information relating surface quality from many users but differs in that the IntelliBike is using people's opinions to create a rating system.

A study by Olieman, Marin-Perianu R and Marin-Perianu M (2012) used accelerometers to measure the level of vibrations at four positions on a bicycle and determined the effects of the road surface, speed, wheel type, and tire pressure on the level of vibrations, they found what the author had seen from earlier studies, that surface type, bicycle speed, and tire pressure have a significant influence on vibration levels, tire pressure will vary from person to person during the perception study however a target of a casual sped of between 9 and 12 miles per hour is set for people taking part.

The IntelliBike

The IntelliBike is an instrumented bicycle capable of monitoring cycle path surface quality through onboard measuring and logging devices, as well as other key variables pertinent to infrastructure and environmental quality, the IntelliBike is intended to depict digital moving images with defect and hazard presentation, the correlation of measured vibrations (on-bicycle) with surface running quality, the correlation of mapping of camera images onto positional and topographical data. The overall IntelliBike project plan and data management system is shown in Figure 1. The bicycle will allow local authorities to see the quality of their off-road cycle path infrastructure and allow them to plan where best to spend their money. The IntelliBike project started as a walk over survey which essentially was the IntelliBike without the bicycle; the walk over survey was developed to find which variables influenced off-road infrastructure the most, the survey was conducted from October 2010 to January 2011, and enabled the author to find the most pertinent variables, with the walk over survey and literature review the authors decided a bicycle would examine surface quality in a fast and economical manner.

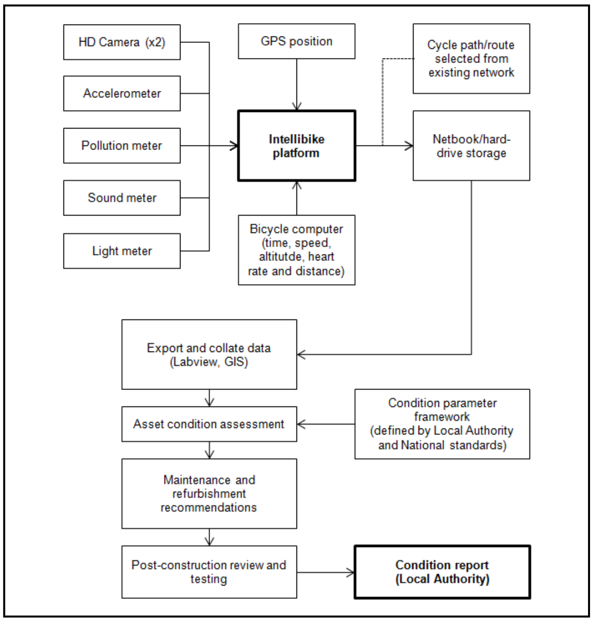

Fig.1 IntelliBike instrumentation and process flow diagram.

The IntelliBike prototype bicycle is a TREK 2012 6000 19.5". The bicycle is a typical robust off-road bicycle that has the ability to lock its front suspension. This feature is useful as lots of cyclists use bicycles without suspension, as the authors are developing a universal vibration rating system to take into account all path users the bicycle must not dampen the excitations caused by defects. Currently the bicycle is fitted with two HD camcorder's, a vibration logger, and a net-book for data logging purposes; for different studies the bicycle is also fitted with a sound meter, a light meter, and a bicycle computer. Table 1 lists the equipment and specifications as well as key parameters which the device measures. The vibration logger is connected to the data-logger and logs to a one second scale.

Figure 2 shows where each device is fitted, the front facing camera, bicycle computer, light meter, and sound meter are all connected to the handlebars; the downward facing camera is fitted to the front fork; the vibration logger is connected to the seat stay, which allows vibration experienced when sitting to be logged; the data-logger is contained within the waterproof box fitted to the rear bicycle rack.

Device	Name	Specifications	Parameters
Camera 1 (A)	GoPro Camera HD Hero2 Outdoor Edition	**Resolution:** 1080p: 1920×1080 – 30FPS **Weight:** 95g **Dimensions:** 42 mm x 60 mm x 30 mm	Path width, vegetation levels, signage quality, surface defects.
Camera 2 (B)	Contour Plus 2	**Resolution:** 1080p: 1920x1080 – 30FP **Weight:** 156 g **Dimensions:** 34 mm x 98 mm x 60 mm	Surface type
Bicycle computer (C)	Garmin Edge 800 Touch-screen GPS Bike Computer	**Features:** High-sensitivity GPS receiver, stays locked on while under tree. Water-proof to IPX7 standards **Weight:** 98 g **Dimensions:** 51 mm x 93 mm x 25 mm	Latitude, longitude, altitude, speed.
Sound meter (D)	ATP Precision logging sound level meter ASL-8851	**Frequency range:** 31.5 Hz to 8 KHz **Range:** 30 – 130 dB **Resolution:** 0.1 dB **Weight:** 350 g **Dimensions:** 278 mm x 76 mm x 50 mm	Sound level
Light meter (E)	ATP LX-8809A SB Data-logging light meter	**Lux measuring ranges:** 0 to 400, 4000, 40000, 400000 Lux **Weight** 390 g **Dimensions:** 230 mm x 80 mm x 50 mm	Light level
Vibration logger (F)	Madge Tech Shock 101	**Sample rates:** 1.953ms/512 Hz **Range:** ±5 g **Calibrated accuracy:** ±0.2 g **Acceleration resolution:** 0.001 g **Real-time recording:** 1 second or slower reading rate **Reading rate:** 64Hz to 5 minutes for shock **Dimensions:**89mm x 112mm x 26mm **Weight:** 340 g	Surface quality
Data logger (G)	Acer Aspire One D270 10.1 inch Net-book	**Processer:** 1.6 GHz **Ram size:** 2 GB **Hard-drive:** 500 GB **Screen size:** 10.1 inches **Weight:** 3.5 kg **Dimensions:**618 mm x 394 mm x 90 mm	-

Table 1 Equipment and bicycle information.

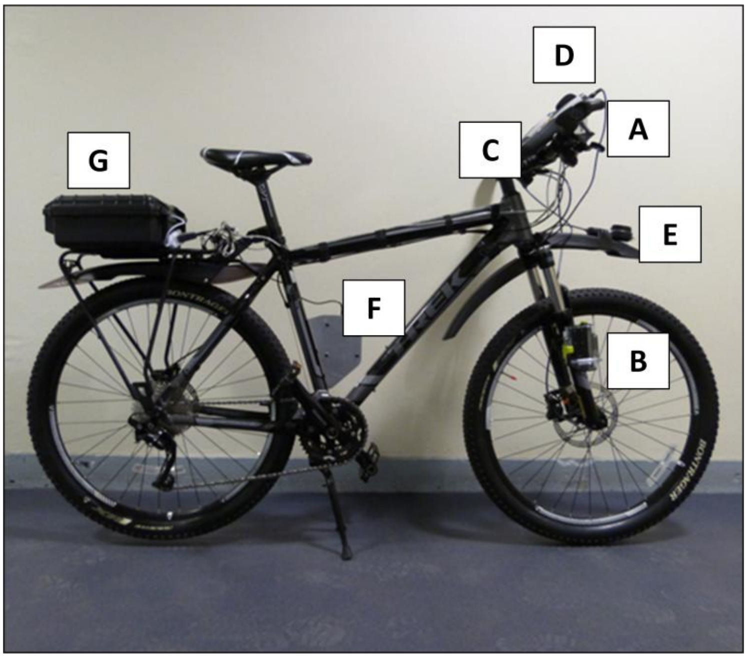

Fig.2 The bicycle with measuring devices and equipment.

Comfort perception study

The use of a vibration logger facilitates categorisation of surface quality that can then be used for surface maintenance purposes. A rating system must then be designed. The MadgeTech Shock 101 vibration logger collects vibration levels as it the IntelliBike is cycled along a path and can pick up different levels of vibration depending on the surface type and whether or not there is a defect, however this raw data is not categorised into different levels of quality. Thus a comfort perception study was created that draws the opinions of many different cyclists together and uses them to map to the vibration logger which in turn will have its vibration levels mapped to the opinion of the users and create a rating system.

A wide selection of users have thus far conducted the comfort perception test and can be categorised into different groups for age, gender, cycling experience, fitness levels, and bicycle type. The users conduct their test on their own bicycle as this allows for the rating system to have a wide collection of bicycles in its development.

The user perception study is broken up into two parts. For the first part the users complete a short questionnaire asking them a few cycling related questions, they are also giving 20 pictures of different surfaces and defects and asked to rate how comfortable look purely from a visual standing, they categorise the pictures as 1 – Excellent, 2 – Good, 3 – Average, 4 – Poor, and 5 – Awful. For the second part of the test the users cycle three short routes in the Meadows, Edinburgh, which is a park with numerous off-road cycle paths. The three routes are roughly five hundred metres each and only take a few minutes to cycle at a casual pace, the routes are of varying quality and have defects and surfaces in which comfort will vary, all routes are made of solid surface types, Figs.3, 4 & 5 show the start points of each route. When cycling the routes the cyclists give real-time feed back as to their cycling comfort level generated by the vibration of the bicycle on the path surface. User's bicycles are fitted with an onboard camera and microphone which logs their opinion as to their comfort levels (1-5); their bicycle is also fitted with a bicycle computer which logs their distance, locations, speed, and time.

Fig.3 Route 1 (New smooth surface)

Route 1 is a wide segregated pedestrian/cyclist path, the path has recently laid so overall it is a excellent quality path with users universally agreeing with that level, as it is a new path there are no defects along it.

Fig.4 Route 2 (Old smooth surface with hazards)

Route 2 is an older path than route 1 and is again a segregated pedestrian/cyclist path, the path is overall of still a good quality however where are numerous surfaces abrasions as well as raised sections that can be hazardous if not approached properly, users are more split with rating this path with some people more tolerate to the larger vibrations endured from the raised surface and abrasions.

Fig.5 Route 3 (Old rough surface with defects)

Route 3 is a mixed path is has the worst surface of the three, there are many rusts and bumps along this path and has almost universally suffered from surface abrasion of the years, again this path has mixed rating levels from people, most agree with rating their comfort on the negative end of the scale while others still fell that their discomfort is minimal.

The authors are targeting conducting the test with at least thirty users; thus far the tests have gone as expected and on this current trajectory the perception study will allow for a full rating system to be developed. Feedback from users has been positive during the tests, they have stated that they feel a five point rating system allows for a broad selection and have praised the simple testing procedure. The varying opinions being gathered shows the different levels of comfort people experience when cycling, typically it is the people that describe themselves as experienced cyclists that have a higher threshold for discomfort. With these broad opinions the rating system being developed should be a commentary on the wider public and thus be an accurate tool. The rider comfort perception study will employ the optimal scaling of categorical data in the statistical analysis of the results.

The perception study is being conducted in order to create a quality rating system for off-road cycle path surfaces, an example of a typical graph for vibration levels in G-Force can be seen in Fig.6, as can be seen this image shows a graph which fluctuates according to the surface type and quality. Spikes in the graph correspond to defects which generate high forces when cycled over, the image shows a defect and the corresponding increase. With the defect detection and user generated surface quality rating system in the vibration logger and the GPS functions of the bicycle computer working together, these devices will be able to accurately plot the overall quality of a path and potentially plot it in a dedicated software platform shown in Figure 7 which will show local authorities where maintenance is required.

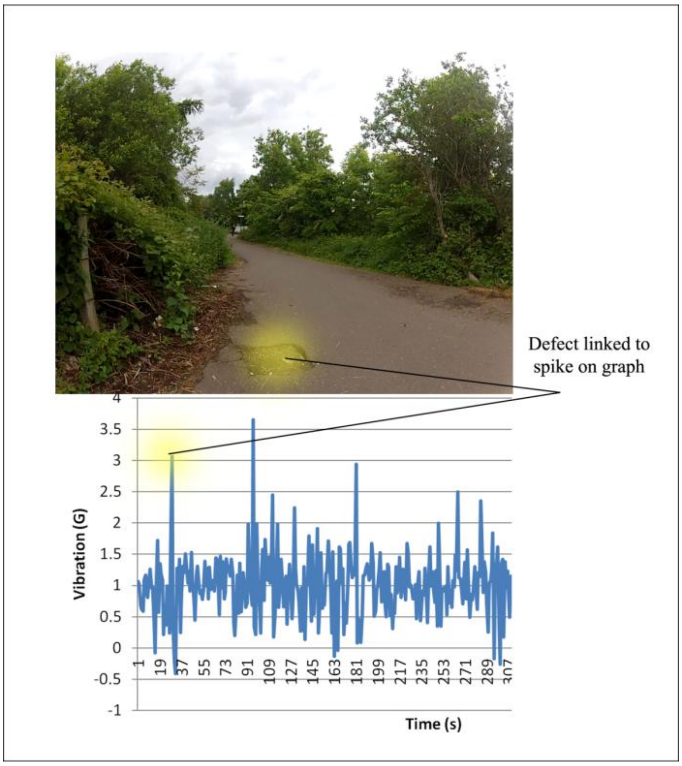

Fig.6 Vibration logger defect spike.

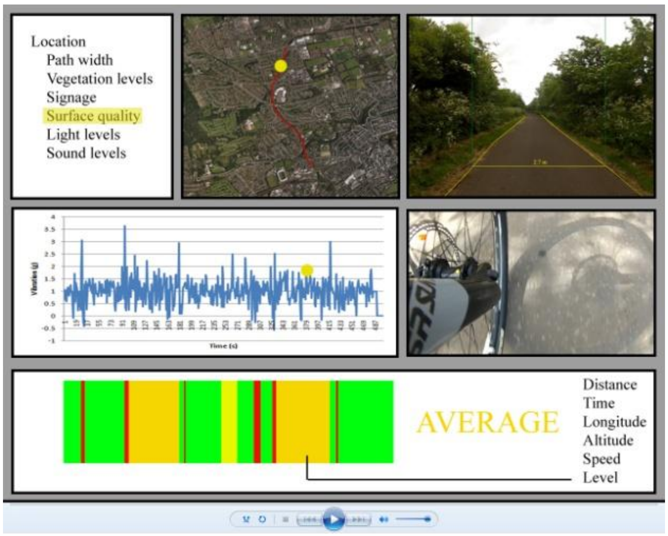

Fig.7 Potential software user interface.

Conclusions

The ongoing testing with the comfort perception study has so far been successful allowing for key feedback from users all the while developing a strong database of users comfort levels from path surface quality along the three short paths. With the target of thirty users drawing closer mapping of the statistical data gathered will soon allow for the development of the surface quality assessment tool.

Future work

As the comfort perception study is an ongoing study the authors aim to have as many people as possible take part in order to make an even more broad assessment to peoples perceived comfort levels and thus make a more accurate quality assessment tool. With the completion of the comfort perception study the authors aim to trial the IntelliBike with the user developed rating system throughout Edinburgh and develop the rating levels for the other key variables which the IntelliBike looks at.

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