Smart Bikes for Smart Cities[1]

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Executive summary: *The authors have developed a situation aware* electrically-assisted bicycle (known as a 'pedelec' or 'e-bike') *that can provide services to help people in cities. These services can contribute to solving a number of city problems such as road congestion, air pollution and energy sustainability. Smart closed-loop control algorithms are implemented on the bike in order to achieve a specific objective.*

Extended Abstract

1. Platform:

Data acquisition system:

The e-bike has been retrofitted with a number of sensors to measure data from the bike when cycling such as pedal torque and wheel speed. It is planned that the e-bike will also be equipped with a number of environmental sensors to measure levels of atmospheric pollutants in real time. Data gathered from the bike is transferred wirelessly (by Bluetooth) to a smartphone. Other data streams are also sent to the smartphone including data from a wearable activity tracker e.g. Microsoft Band. Data of particular interest from the activity tracker includes heart rate data and metabolic calories burned data. Any stream of information available on the smartphone may also be added to the data acquisition system e.g. Google Maps location and traffic data.

Control system:

Data is processed in a feedback loop on the smartphone. The variable of interest, which depends on use case, is compared to a target value and this is used to calculate an error. The relationship between this error and the control output depends on the model of the plant (human and e-bike system). This model is use-case specific. Different use cases require having a model which takes into account different factors such as the specific cyclist's biology or the cycling environment (e.g. topography, wind speed and direction, local air quality). The output of the feedback control loop is used to actuate the e-bike motor. In practise the control output is sent wirelessly from the smartphone, translated to a PWM signal and then to an analog voltage which is sent to the main controller of the e-bike and finally to the e-bike motor.

2. Use Cases

1) Connected personalised activity tracking services:

The e-bike has been connected to an activity tracker (specifically a Microsoft Band) using Bluetooth. This enables the delivery of personalised services for cyclists. For example, a cyclist is

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[1] Extended abstract for Fraunhofer Morgenstadt meeting, Dublin, March 10th, 2017, http://www.morgenstadt.de/en/Events.html. The full version of this paper will be available in the Proceedings of the 18 Yale Workshop on Adaptive and Learning Systems; see https://www.eng.yale.edu/css/.

able to set a goal for the number of Calories (kcal) that they wish to burn during a cycling trip. The smart control algorithm on the smartphone then compares the cyclist's target to their performance (actual Calories burned) in real time to calculate an error. This error is then used to determine the amount of electrical assistance that the e-bike will provide to the rider for the next time interval. For example, if the cyclist has not burned as many Calories as they should have then the e-bike will provide less assistance to get them back on track. Calories is given as an example here but this can be extended to any data input available from an activity tracker e.g. heart rate.

2) Proactive pollution control:

The amount of air pollutants (NOx, PM etc.) that a cyclist inhales increases with their breathing rate. As such it is desired that when a cyclist is cycling through a polluted area in a city that the volumetric amount of air that they inhale is minimised. This can be achieved by ensuring that the e-bike gives an increase in electrical assistance to the cyclist when they are going through a polluted area. This means that the cyclist has to provide less power to move the wheel of the bike which causes their breathing rate (and heart rate) to reduce. Since it is impractical to continuously measure a cyclist's volumetric air intake as they cycle, the measurement of cyclist heart rate from the activity tracker is made use of here for verification purposes. The determination of whether an area is polluted or not can be based on direct measurements e.g. using information from local air pollution sensors or indirectly inferred e.g. from Google Maps traffic data. [1] [2] [3]

3) Smart routing:

A cycling trip between two nodes in a geographic network (a typical example would be a commute from home to work) could be traversed by a number of different paths depending on the network topology. The path that is taken to travel between the starting and final node can be selected to achieve a certain objective e.g. to minimise journey time, to maximise the final state of charge of the e-bike battery, to avoid hills or to minimise exposure to pollutants. As such routing algorithms can be developed in order to inform a cyclist which route they should take in order to achieve their objectives. GPS data is available from the smartphone which provides location data and lets the routing algorithm know the starting node in the network. The final node of the network can be determined either by (i) the cyclist directly informing the e-bike or (ii) using predictive analytics based on historical routes taken by the cyclist. [4]

4) Energy Management:

Electrically assisted bicycles can help to solve many road transport problems including congestion, parking and air pollution. An e-bike makes use of a battery which is rechargeable using electricity and as such there are no incremental emissions of greenhouse gases or harmful pollutants from the e-bike when it is providing assistance to the rider. However, the authors recognise some of the barriers associated with cycling that do not exist for other forms of road transport (specifically the ICE vehicle) such as a cyclist being limited by their physical fitness. As such it is important to ensure that barriers to cycling are overcome insofar as possible. An energy management system to monitor and manage the state of charge of the battery is therefore essential. The energy management system can be used to ensure that a cyclist receives assistance from the e-bike at the times when they need it most e.g. going up a hill. Also of particular interest here is the potential to integrate regenerative braking into the system in order to recover energy to recharge the battery. [5] [6]

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