Development of Instrumented Bikes: Toward Smart Cycling Infrastructure and Maintenance

PI: Chun-Hsing Ho

Northern Arizona University (previously employed)
University of Nebraska-Lincoln (currently employed)
Email address of PI: chunhsing.ho@unl.edu

Co-PIs: Brendan Russo and Steven Gehrke

Project Objective

This project is to develop an instrumented bike with a sensor logger, a video device (e.g., GoPro), a mobile app, and a cloud server/website to detect real-time quality of cycling infrastructure systems (bike trails, sidewalks, pedestrian pathways, etc), and immediately share the information with cyclists (road users) and governments/authorities (road managers) such that (1) cyclists (road users) will be aware of upcoming potential hazards prior to cycling and be able to adjust their cycling route accordingly, and (2) governments (road managers) will be able to effectively prioritize their maintenance needs. The purpose of the project is to introduce an instrumented bike to the cycling community and agencies with a goal to provide “smart wheels” for day-to-day cycling operations, improve bike efficiency, safety, and mobility, promote cycling activities, and reduce emissions

Problem Statement

The market of connected vehicles has been growing dramatically in recent years; with the global market expected to reach $225.16 billion by 2027. However, as a part of intelligent transportation systems, the use of geospatial and remote sensing in cycling mobility has yet to receive significant attention, likely due to limited efforts in manufacturing instrumented bikes or smart bikes to actually promote cycling mobility and reduce greenhouse gas emissions. Particularly, during the current COVID-19 pandemic, the encouraging of cycling can decrease exposure to others on public transport, reduce air pollution, and promote improved health and well-being. While cycling on bike facilities, the roadway surface structure plays an important role in bike ride quality. With the continued growth in cycling activity and infrastructure throughout the country, the question of how to obtain real time information on cycling facilities that would help better maintain the quality of these facilities and provide safe environment for cyclists has become a concern among city, county, and state engineers. The use of sensors/accelerometers attached on bikes have been investigated by numerous researchers to study cyclist behavior, monitor cycling motion, and measure the force of pedaling, however this technology presents an untapped potential to assess bike facility surface conditions. There is an urgent need to meet increasing demands for cyclist safety to motivate increased activity, thus the research team believes that the interactive behavior of cyclists plays an important role in bringing together improved bike mobility and community engagement. More importantly, how to encourage cycling activities through a well-designed program, and enable riders to stay connected has been a challenge nationally

Research Methodology

The project began with the design of sensor logger consisting of a microprocessor with a Wi-Fi module, accelerometers, Global Positioning System (GPS) unit, and a battery system followed by a few field tests performed by four different cyclists including male and female and varying bikes. The report started with introduction of the project and the background of instrumented bike (Chapter 1). Based on our

previous research work, a threshold method to identify severity level of cycling facilities is not considered as an effective approach. Thus a generic deep learning based computing algorithm using the sliding window method was developed in support of the development of instrumented bike (Chapter 2). We conducted two different field tests on paved and unpaved cycling facilities/trails on the Northern Arizona University campus and the City of Flagstaff bike trails with goals to evaluate the effectiveness of sliding window computing algorithm in identification of potential hazards (bumps, potholes, uneven surface, cracks, etc) known as point of interest (POI). A list of the severity level of cycling facility ratings was conducted on the two paved cycling trails (Chapter 2). In addition, the existing conditions of the bike facilities (both paved and unpaved) were compared against the guidelines set forth in the American Association of State Highway and Transportation Officials (AASHTO) Guide for the Development of Bike Facilities and the Manual on Uniform Traffic Control Devices (MUTCD, 2012) (Chapter 3). The conclusions and recommendation were provided in Chapter 4

Results

Based on the results, the project concluded that the sliding window computing algorithm is capable of analyzing vibration patterns and identifying potential hazards (PIOs) through multiple cyclists; it has achieved the state-of-the-art performance in classifying and localizing cracks/potholes without any human-controlled supervision (e.g., annotated dataset used to train the classifier; threshold adjustments for distress classifications) while achieving human-level perception. The development of instrumented bike provides a promising methodology to (1) help local government or agency in reviewing existing cycling trail conditions based on real time cycling information such that a list of repair priorities can be provided for decision making for maintenance and (2) share the results with cyclists so allowing them to adjust cycling routes prior to cycling.