Effect of Cycling Skills on Bicycle Safety & Comfort associated with Infrastructure & Environment

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Primary Goal

- Study ‘Bike-ability’ and ‘Bicycle Safety & Comfort’ via quantitatively analyzing the effect of
  - the level of cycling skills
  - the bicycle infrastructure and environment

- Bike-ability?
  - British Government approved National Standards for Cycle Training Program based on
    - cycling proficiency
    - to extent to which an environment is friendly for bicycling
Objectives (1)

- Develop
  - Instrumented Probe Bicycle (IPB)
    - to measure and analyze a set of Dynamic Motion Variables (human control inputs and bicycle kinematic variables) through *in situ* experiments
  - Simulation Model for Bicycle-Rider Dynamics
    - to investigate human/bicycle dynamics and control using analytical approach and compare to IPB experimental results
  - Survey-based Assessment Method
    - to quantify different level of cycling skills based on a set of objective questions
    - to investigate Bicycle Safety & Comfort associated with Cycling Infrastructure & Environment based on Rider Perceptions
Objectives (2)

- **Establish**
  - Quantitative, measurement driven ‘Bike-ability’ criteria via finding functional relationship among
    - the level of cycling skills
    - bicycle safety and comfort
    - cycling infrastructure and environment
  - A possible prediction model for Bicycle Comfort
“A Global Review of Current IPB Technology and Research” - 2014
- Mohanty et al
  - Comprehensive survey on IPB research around the world
  - Suggests the direction to improve IPB technology and thereby promote bicycling

“Understanding Bicycle Dynamics and Cyclist Behavior From Naturalistic Field Data” - 2014
- Dozza et al
  - Presents a IPB design and shows how collected data can support the development of intelligent systems by offering novel insights into bicycle dynamics and bicyclist behavior
  - Offers the first tangible contribution to understanding cycling behavior and bicycle dynamics from field data
“An Experimental Investigation of Human Bicycle Dynamics and Rider Skills in Children and Adults” - 2013
- Ph.D. work by Stephen Cain @UofM
  - to identify performance metrics that reliably distinguish rider skill level
  - Introduced IPB to measure rider control and bicycle responses as well as analytical approach to investigate the rider-bicycle dynamics

“Human Control of a Bicycle” - 2012
- Ph.D. work by Jason Moore @UC Davis
  - Most up-to-date comprehensive work on Nonlinear & Linear Mathematical Modeling of Rider-Bicycle Dynamics and Control, IPBs research at UC Davis with the summary of earlier Delft’s IPB work
“Using Instrumented Probe Bicycle to Develop Bicycle Safety and Comfort Prediction Models” - 2014
- Lee et al
  - Developed a bicycle comfort and safety prediction models, utilizing IPB equipped with camera, time-of-flight sensor, potentiometer, and GPS
  - Discovered, type of bike path, space, cycling speed, cyclist demographic, and traffic volume are the most significant factors affecting rider comfort and safety

“Evaluation Models for Cyclists’ Perception Using Probe Bicycle System” - 2013
- Yamanaka et al
  - Suggested evaluation models from a viewpoint of bicycles and studied five aspects: traffic, roughness of road surface, narrow bicycle space, cycling speed, and total level of comfort.
  - The model was used to provide LOS index.
“A novel method to monitor bicycling environments” – 2013
  - Joo et al
    - used an IPB to develop the Bicycle Monitoring Index (BMI). BMI was used to evaluate two aspects of bicycle environments; safety & mobility

“Preliminary results from a field experiment on e-bike safety: speed choice and mental workload for middle-aged and elderly cyclists” – 2013
  - Twisk et al
    - studied the safety of electrical assist bicycles on the elderly, utilizing IPBs equipped with a speedometer, a GPS, a camera, an inertial measurement unit, and a potentiometer to record steer angle and steer acceleration
**IPB Sensor Suite**

<table>
<thead>
<tr>
<th>Sensors</th>
<th>Data &amp; Functions</th>
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</thead>
<tbody>
<tr>
<td>Inertial Navigation System (INS)</td>
<td>3 axis linear acceleration &amp; angular rates; estimated attitude angles &amp; 3 axis velocities;</td>
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<tr>
<td>Global Positioning System (GPS)</td>
<td>Position compensated with INS</td>
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<tr>
<td>Steering Input Potentiometers</td>
<td>Steering angle</td>
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<tr>
<td>Wheel RPM Encoders</td>
<td>Front &amp; Rear Wheel Speeds</td>
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<td>Body angles Pots (Control Input)</td>
<td>Tilt (longitudinal) &amp; Lean (lateral)</td>
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<tr>
<td>Video Camera</td>
<td>Traffic volume &amp; rider environment</td>
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Details on Experimental Settings

- The experiment site is located at WMU.
  - 0.9 mile long route starts from W. Michigan Ave ends at the same location through Howard St, Valley Rd, and Rankin Ave.
  - participants may ride either on sidewalk or travel lane by their own choice.
- Duration of experiment per rider is between 5 to 7 minutes
- Features on Experimental Route
  - straight section with shared lane
  - up and down slope (3%) & Horizontal curve
  - signalized intersection with high traffic volume and another one all-way-stop intersection
  - roundabout could be optional by introducing alternative route at the sidewalk
In Situ Experiment (2)
Pre-Experiment Survey

- The participants will be asked to provide their bicycle experience, skill level and confidence
  - How often do you ride bike? (daily, weekly, monthly, rarely)
  - What is your primary purpose of bike trip?
  - How many miles do you ride a week? (0-5, 5-10, 10-20, 20-30) miles
  - How confident do you feel when you ride in the following facilities? Rank your cycling confidence level? (bile lane, shared lane,..)
  - How do you rate your cycling skills? (highly skills, .....
  - How many years have you been a cyclist? (>1, 2-3, 4-6, 7-10, 11-15)
  - How would you classify yourself as a biker? (beginner, moderate, experienced)
  - Do you belong to a club or team?
  - Do you have a cycling coach or have you been coached?
Post-Experiment Survey

- Post survey will be primarily used to identify Bicycle Safety and Comfort associated with Bicycle Infrastructure & Environment

- Route is segmented based on
  - Bicycle Traffic Infrastructure (bicycle lane, shard lane, etc.)
  - Traffic encounter
Preliminary Trial Results

- 8 Participants
Rider Control Input (1)
Rider Control Input (2)
Bicycle Kinematic Variable (1)
Bicycle Kinematic Variable (2)
Spectral Frequency Analysis

Steering Angle

Amplitude Spectrum of Lean

Rider Lean
Scheduled General Public Ride Experiment
- HSIRB Approval granted
- Recruiting Effort
  - invitation sent to local (Kalamazoo & Portage) bicycle groups
  - WMU Campus wide announcement
  - attempting to link up with the annual WMU BTR Bicycle Racing Event on 7/9/2016

Data Processing & Analysis
- automate the data processing for effective analysis
- time-domain and frequency-domain analysis of measured dynamic variables
- extract necessary information (such as descriptive statistics) to characterize cycling skills among different level of proficiency
Analytical Modeling & Simulation of Rider-Bicycle Dynamics
- Multi-body dynamic analysis based on Kane’s Approach
- Through analysis, understand stability and control characteristics among different levels of cycling proficiency

Bike-ability Model Development
- Employ DOE or Profit Modeling to construct a functional relationship between Cycling Proficiency and Safety & Comfort
- Include the effect of Bicycle Infrastructure & Environment into Bicycle Safety & Comfort using experimental data (dynamic variables & recorded video) and survey-based quantification data.
Thank you! Any Questions?