Experimental Validation of Bicycle Handling Prediction

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1 INTRODUCTION

In prior work, a theoretical model of a bicycle rider control system has been proposed [1]. The model was adapted from pilot modeling efforts previously reported in the literature and consists of feedback gains as a function of bicycle physical parameters and speed. It includes a value for the handling quality metric (HQM), a measure of the ease with which the bicycle can be controlled in a given task. The model can be a powerful tool in analyzing safety of current designs as well as lead to safer new designs with improved handling qualities that may decrease bicycle related injuries [3]. The purpose of the present research is to find experimental evidence that validates this model.

2 METHODOLOGY

Our goal is to construct a bicycle with a single variable physical parameter strongly affecting handling that can be easily, discreetly, and accurately adjusted. To do this, we manipulate the moment of inertia I of the front handlebar and fork assembly (front assembly) about the steer axis, by adding a mass to the front assembly at the same vertical position (Fig. 1a) as the nominal center of mass but with variable horizontal position d. The modified moment of inertia can then be calculated using the parallel axis theorem. Increasing d increases the parameter I which results in a larger predicted HQM and poorer predicted handling. Calculations using the model from [1] were used to find plausible masses and positions that could be effective experimentally.

An experimental bicycle was constructed so that a 5.11 kg weight could be moved to different positions along a pipe so that I could be easily changed, Fig. 1b. Participants were instructed to ride the bicycle as slowly as possible (approximately 0.7 m/s) and to attempt to keep the rear wheel centered on a painted straight yellow line (Fig. 2a). Participants rode the experimental bicycle multiple times with the mass at different positions. Changes in I are most noticeable to riders at low speeds. A 30 Hz GoPro camera was attached to the rear rack aimed at the ground and a centerline mark was drawn on the fender in the view of the camera. Chalk lines were drawn on the ground denoting 10 cm increments from the center of the yellow line. The videos were examined at every 6th frame to extract a lateral position of the projection of the fender mark on the ground, Fig. 3. Note this position is not exactly the same as the wheel contact point because effects of bicycle roll and yaw were neglected. Chalk lines to the left of the yellow line were considered negative while lines to the right were considered positive.

3 RESULTS AND CONCLUSIONS

The standard deviation of the rear wheel lateral deviation from the center line describes how unable the rider is to follow the desired path and thus how difficult the task is with that particular mass placement. Figure 2b indicates that lateral deviation increases when the mass is added to the bicycle's front assembly. Furthermore, these preliminary results lead us to believe that our hypothesis that the lateral deviation will increase as *d* increases may hold true with a more carefully controlled experiment and more trials.

The HQM is a numerical measure of the difficulty of controlling the bicycle in any task [1]. Although what was measured in these experiments (standard deviation of lateral deviation) was not the HQM per se, nevertheless we believe that it is clearly related to the HQM. Our future work will explore this relationship between the above objective measures and handling as well as investigate rider subjective ratings to more fully develop the proof that support our hypothesis. Our ultimate goal is to validate the handling prediction concept presented in [1].

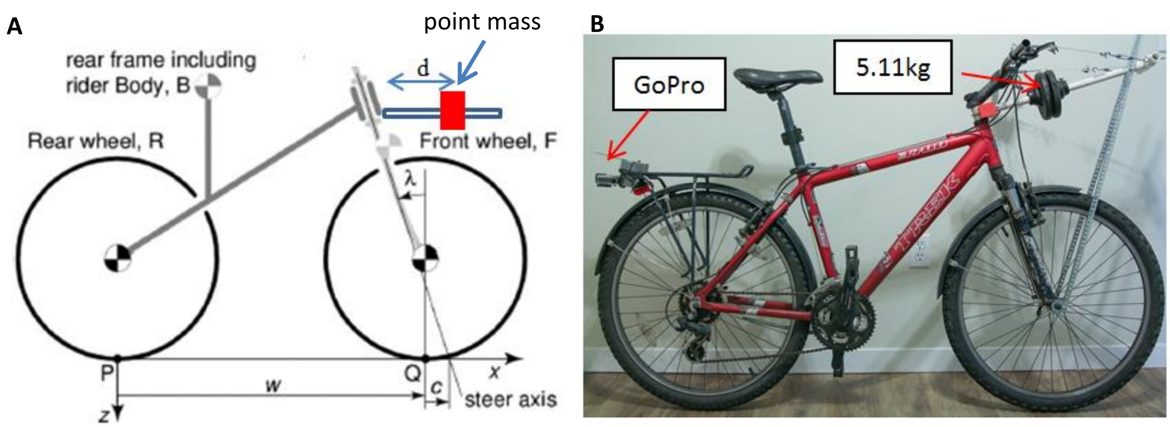

Figure 1: Theoretical and experimental bicycle schematics. Fig.1a is adapted from [2] *and depicts the idealized additional point mass. Fig. 1b shows the preliminary physical realization with a 5.11 kg mass mounted on a bar extending from the steer tube.*

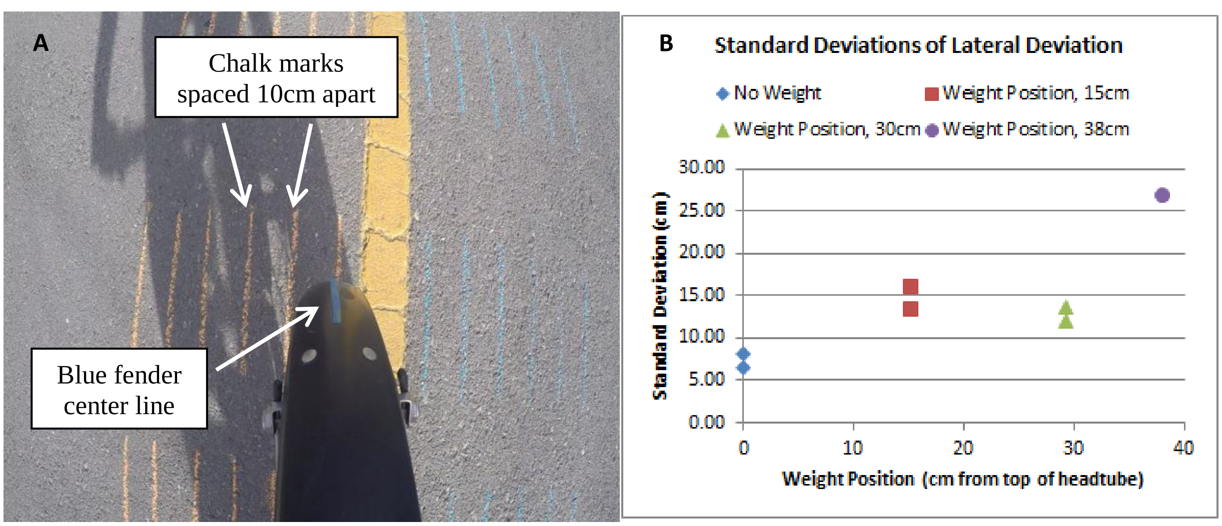

Figure 2: a) Rear wheel lateral position of blue fender center line from center of desired (yellow) tracked line was measured using a downward pointing GoPro camera yielding b) standard deviations of lateral deviation vs mass position d.

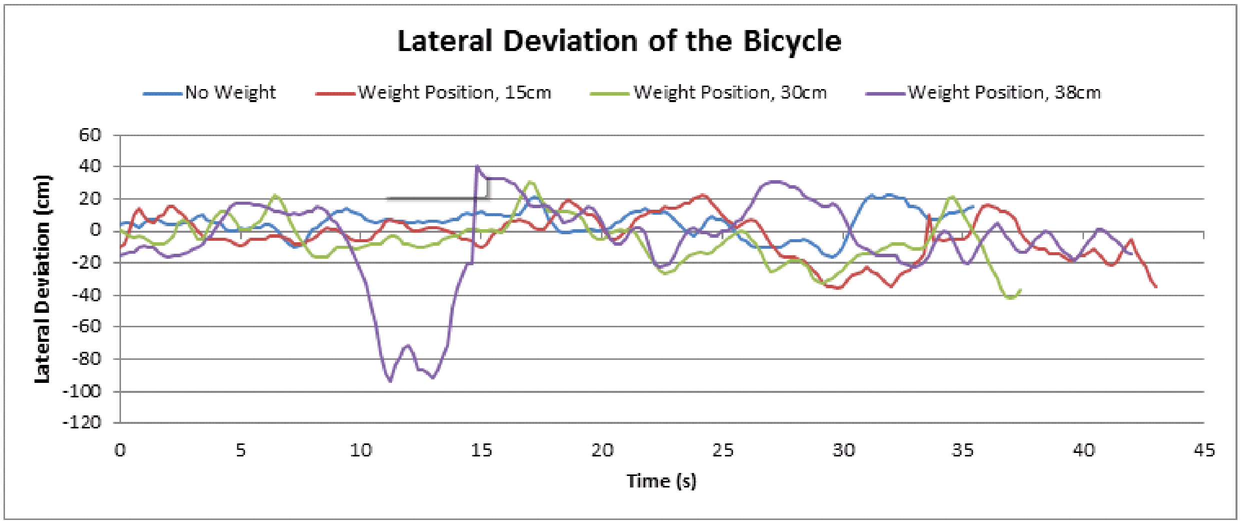

Figure 3: Measurements from downward pointing GoPro camera yielded experimental lateral deviation traces versus time

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