Type of the Paper: Extended Abstract

Data Collection for Learning the Dynamics and Control of an Electric Unicycle

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Abstract:

The spreading of micromobility devices in road transportation systems can open many possibilities. Balance assisted single-wheel vehicles (also called electric unicycles or EUCs) can solve transportation problems in unique ways. Due to their design, they can fit into tight spaces, they do not have significant weight, and their acquisition and maintenance costs are relatively low. For personal travel and for carrying small packages unicycles offer a competitive alternative in urban transportation. In addition, performing delivery tasks in driverless mode may also be feasible considering the simplicity of such mobile robots and their resemblance of human delivery personnel. However, the upright position of such micromobility vehicles is typically unstable. This provide unicycles with high level of maneuverability, but at the same time, they require skilled riders (or high performance controllers) to ensure safe operation (Sheng and Yamafuji, 1995).

In this paper, an experimental method suitable for analyzing the motion of an electric unicycle and its rider is introduced. The main motivation behind the experiment is to learn how humans balance and maneuver while riding the EUC. This may help us in evaluating the safety of human rider, design balance-assist features and/or self-driving functionalities. Our results provide data for later analysis of a human-ridden electric unicycle for a variety maneuvers.

Specifically, we collected data for 34 runs of 7 different maneuvers using 2 riders of different levels of balancing skills. An *OptiTrack* motion tracking system with 12 cameras covering a volume of approximately $4 \times 6 \times 2$ meters was utilized (Molnár et al., 2021). These sensors provide high-precision position and orientation data for each body part defined by a set of markers as shown in Fig. 1. From the *OptiTrack* system, the (x, y, z) coordinates of a predefined pivot point and the orientation angles (yaw, tilt and pitch) are obtained for each body part. The pivot points are mostly set to be human joints and they are shown in white circle where the axis located at each rigid body in Fig. 1(c).

The data collected via the *OptiTrack* system for the EUC and helmet are presented in Fig. 2. These graphs represent a figure-8 maneuver, which is a complex motion because it can be accomplished by turning in relatively large angles around all the three axes. Panel (a) shows the trajectory of the helmet (red line) and the EUC (blue line) in 3D space while making a full figure-8 pattern. It can be seen in panels (b)–(d) that the orientation of the head differ from the orientation of the EUC. This can be explained by the fact that the local coordinate system of the helmet follows the direction the rider is looking at. Using numerical differentiation and data smoothing techniques, the velocity, acceleration, angular velocity and angular acceleration of each rigid body can be obtained from
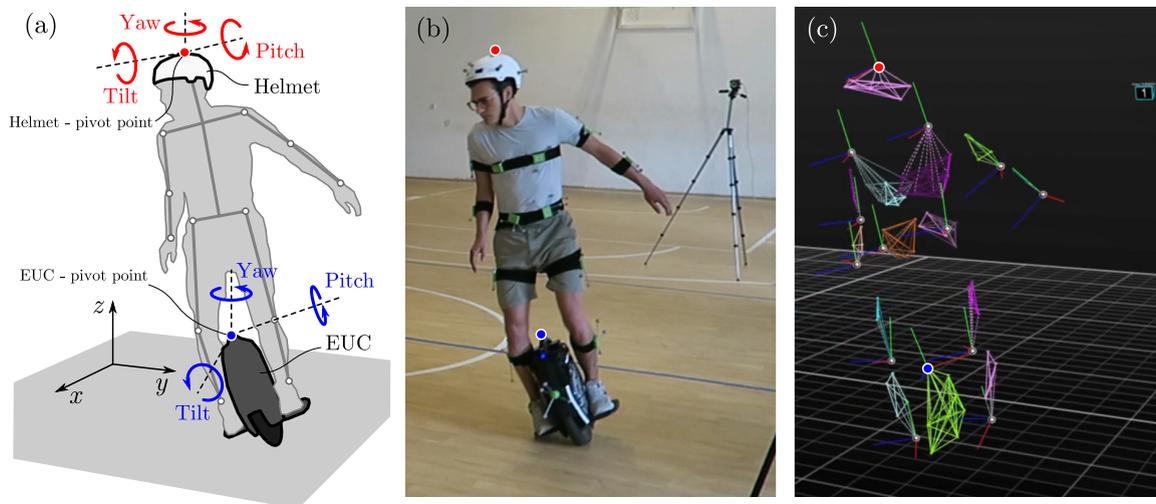
Figure 1. (a) Simplified skeleton model of the human rider on the EUC with the definitions of the pivot points, yaw, tilt and pitch angles. Turning maneuver with the reflective markers in normal camera view (b), and OptiTrack view (c) displaying the corresponding body segments as rigid bodies with the pivot points.

data. As a next step, we will use the measured data to predict the acceleration and angular acceleration. Neural delay differential equations with trainable delay (Ji et al., 2021) will be utilized for learning to capture the reaction time delay (Insperger and John, 2021) of the human rider. These will be combined with a principle model to predict the torque component applied on the EUC by the rider.
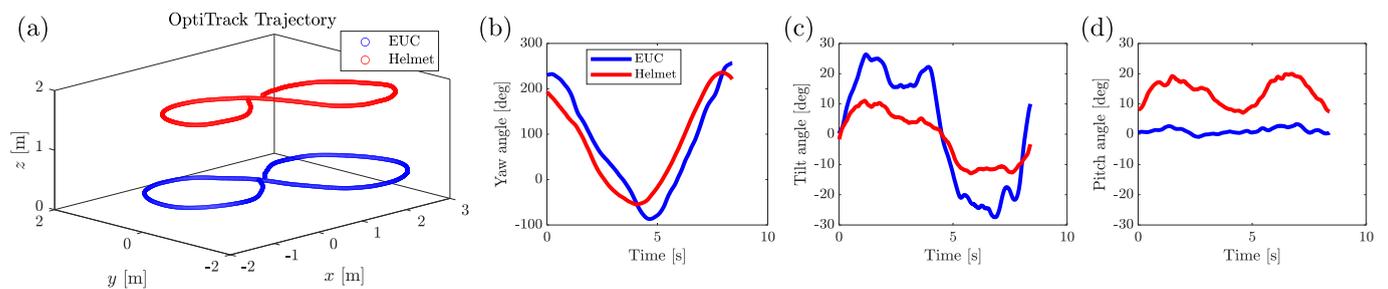

Figure 2. Data obtained from OptiTrack related to figure-8 maneuver: trajectories of two specific rigid bodies (a), and their time series of angles to determine the orientation (b)–(d).

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