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A depth camera-based system for estimating cyclist-bike projected frontal area

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Abstract

A major component of total resistive force in cycling is aerodynamic drag. For speeds greater than ~14 m/s aerodynamic drag accounts for approximately 90% of total resistive force (Debraux et al., 2009: International Journal of Sports Medicine, 30, 266-272). Together with the air density, the coefficient of drag and the velocity of the cyclist-bike, an important determinant of aerodynamic drag is projected frontal area. Several techniques have been used to estimate the projected frontal area of a cyclist-bike, including the weighing of photographs and image digitising (Debraux et al., 2009). These techniques are similar as they involve extracting the cyclist-bike from a two-dimensional (2D) image and using scaling information from a plane of known dimensions. With the weighing photographs method this is done physically using sensitive weighing scales whereas image processing software is used for the image digitising technique. Both techniques require the collection of a calibration plane, involve considerable post-processing and cannot be performed in real time. We have developed a depth camera-based system for estimating cyclist-bike projected frontal area which addresses these issues. The depth camera algorithm works by creating a metrically scaled, three-dimensional point cloud of the cyclist-bike. The point cloud is projected on to a 2D representation of the scene and the area of the point cloud is calculated using a technique similar to 'voxelization'; points in the cloud occupy spaces in a fine grid – the sum of the occupied grid spaces gives total area. The aim of this study was to investigate the agreement between our new method and the image digitising technique.

After institutional ethics approval, eight regular cyclists volunteered to participate and provided written informed consent. Participants wore their normal cycling clothing and their bicycle was mounted on a stationary indoor trainer. The bicycle was positioned against a white background to help with the image digitising method. Participants placed their feet on the pedals and held the cranks parallel to the floor. A digital camera (Canon EOS 400D, 10.1 megapixel) and Kinect depth camera (Microsoft, Redmond, WA, USA) were mounted on tripods at a height of 1.1 m and positioned 5 m and 2.2 m in front of the participant, respectively. Similar to Debraux et al. (2009), participants adopted two positions on the bike: 1. Upright – upright torso with hands close to the stem and 2. Drops Position – hands on the drops. Three repeat captures were performed in each position, with the participant relaxing between each capture. The digitising method was performed as described by Debraux et al. (2009). Agreement between methods was assessed using limits of agreement (LOA - Bland and Altman, 1986: Lancet, 1, 307-310). A two-way repeated measures analysis of variance (method by position) was used to assess the effect of cyclist position on the systematic difference between measurement methods.

There was no interaction between cyclist position and measurement method (p = 0.201) indicating that the same effect of cyclist position was observed using both measurement techniques. A significant main effect for cyclist position (p = 0.017) indicated that projected frontal area was smaller with hands on the drops (upright: 0.485 m^2, drops: 0.434 m^2). There was also a significant main effect for measurement method (p < 0.001) indicating a significantly smaller estimation of projected frontal area using the Kinect (Kinect: 0.416 m^2, Image: 0.503 m^2). A predominantly systematic difference between methods was also suggested by the LOA analysis (upright: 0.086 ± 0.029 m^2, drops: 0.090 ± 0.033 m^2).

The aim of this study was to assess the agreement between a common method of estimating cyclist-bike frontal area and a new depth camera-based technique. The new technique estimated systematically smaller projected frontal area than the image digitisation method but there was relatively little random variation and the same effect of cyclist position was observed with both techniques. Which technique gives the most accurate estimate of projected frontal area is not clear as the image digitisation technique - to which the new technique was compared - has associated errors e.g. identification of the cyclist-bike outline and out-of-plane errors. However, it was apparent during testing that the depth camera-based system often failed to identify parts of the bike and this is most likely the cause of the difference between techniques. Regardless, the results of this study suggest that the new technique can be used to assess *changes* in projected frontal area – as the cyclist changes position, for example. Further, the new technique offers the possibility of analysing changes in projected frontal area in real time – there is no requirement for calibration or post-processing.

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Received: 1 May 2014. Accepted: 1 June 2014.