BOOK OF ABSTRACTS **Open Access**

First evaluation of an automated system for cyclist's aerodynamic drag assessment

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Purpose:

When riding on a flat road at high speed, the major part of the resistive forces experienced by a cyclist is due to aerodynamic drag. Reducing this drag is thus a key challenge for improving cycling performance. To do so it must be adequately quantified. In this regard, different methods have been proposed in literature: wind tunnel (1), dynamometric measurement (2), deceleration (3), and linear regression (4). Recently, a new approach that couples 3D digitization and computational has been investigated (5-8).

Cyclist's aerodynamic drag measurement: Different experiments have shown that linear regression and wind tunnel methods give great accuracy and repeatability. However, the cost of a wind tunnel session is huge and general public can't use this technology. On the other hand a special infrastructure (track) is mandatory to obtain a good repeatability of the linear regression technique.

Recently, in order to offer cheaper solutions, a new approach coupling 3D digitization and computational fluids dynamics (CFD) has been investigated (5-7) and shows some advantages. First, the operating and equipment costs of such solutions are lower than those of wind tunnel or linear regression. Moreover, the measuring conditions are closer to real world testing than the other approaches. Finally, extensive experiments can be performed with only one set of digitized data, including: (I) simulating different wind and cyclist speeds, (ii) assessing different equipments (e.g., helmet, wheel, etc.) by adding them during the simulation, and (iii) creating virtual scene in order to simulate team pursuit (6) or bunch effect.

However, « 3D + CFD » methodology has some limitations which we investigated in a precedent work (8). In order to address these limitations, we proposed to apply the following improvements: (i) 3D digitization of the cyclist and the bike together; (ii) 3D digitization during a full pedaling cycle (i.e., 3D+t acquisition); (iii) Measurement conditions close to real-world testing (i.e., the cyclist is free to move on his bike during the process); and (iv) aggregation of a number of simulations to obtain a composite value of drag more representative of the reality.

The proposed methodology is based on an automated system that allows digitalizing a cyclist with his bike and then computing their drag. This paper presents a first evaluation of this system.

Methods:

In order to assess the accuracy of our method, we compared the drag forces it computes to the ones obtained using an existing method. First, we built a ground truth dataset which consists of drag forces obtained using regression method (4) at different speeds: 25, 30, 35 km/h. The output power was measured using a full-calibrated Rotor InPower sensor. Temperature and atmospheric pressure were obtained using BME280 sensor (Bosch). The wind speed was measured by Proster MS6252A anemometer. The computing of the aerodynamic drags took account for the wind conditions (lower than 1 m/s). The materials to compute the drag forces are available at the following github repository (https://github.com/ApeiraTechnologies/model_sci_cycling2018). Two positions were studied: upright position and brake hoods postion. In a second time, we used our system to compute the drag forces for the two positions at different speeds.

3D Scanning. The 3D scanning is done using our low cost and real-time acquisition system. This system uses 4 low-cost RGB-D (color and depth) sensors (Microsoft Kinect V2). Foremost the 3D data given by these sensors are merged in a unique 3D field. Then a human 3D body model is fitted from this field. Finally a 3D bike model is merged to the model of the cyclist. The whole process is fully automated and don't need human intervention.

CFD simulation: The CFD simulations were performed with the OpenFoam solver (ESI Group). The cyclist surface was discretized using a polyhedral surface mesh. The numerical wind tunnel consisted of a box with a cross section of 3 m by 3 m and a total length of 6 m. The k-ω-SST turbulence model, due to its ability to correctly model separating flow, was used throughout the simulations.

Results:
The figure 1 show the drag forces obtained by the regression method and our system for a) brake hoods position and b) the upright position. We can note that the data are well correlated but that our system under-estimates the drag (between 13% and 32%). These results are consistent with those of (5) and (6). The table 1 presents the differences of drags between the two positions at different speeds computed with a) the regression method and b) our system. We can note that the obtained values are similar for the two methods.

Conclusion:
These results show that our system can compute drag forces that are coherent with the ones obtained with the regression method (even if under-estimated) and that it is able to measure accurately the difference of drag between two positions.

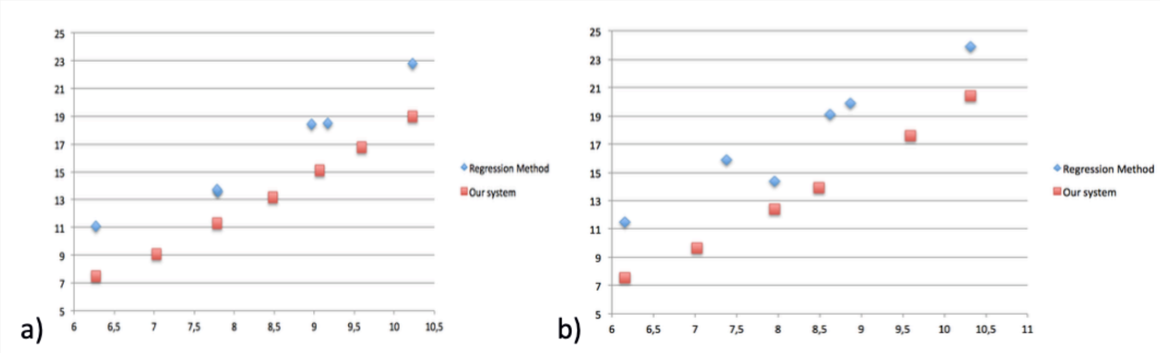

Figure 1. Drag forces obtained by the regression method and our system for a) brake hoods position and b) the upright position.

Table 1. Differences of drags between the two positions at different speeds computed with a) the regression method and b) our system.

a)

Speed (km/h)	22	28	32	37
Difference (%)	3,5	5,7	8,0	4,8

b)

Speed (km/h)	25	30	35
Difference (%)	5,9	5,4	4,9

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