Aerodynamic benefits of optimizing cycling posture

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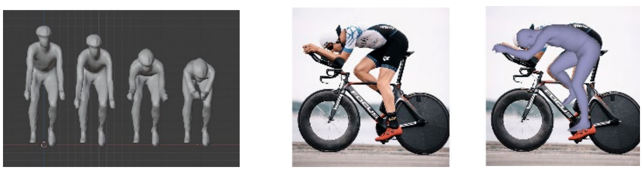
In the following, we describe a unified approach for a workflow to reduce aerodynamic drag during the cycling part of an triathlon. The approach consists of:

- A machine learning approach to deduce 3D triangulation for specific cycling positions as input for a CFD study [1]
- Aerodynamic drag coefficient determination by NablaFlow [2]
- Application to a specific course, Ironman Hawaii, USA



(a) (b) (c)

Fig. 1: (a) Positions investigated by CFD, from left to right Hand on Hoods (HH), Hands in Drops (HD), Dropped Body (DB), Time Trial (TT) (b) side view, (c) 3D model generated by eXpose[1].

The investigated positions presented in Fig. 1 (a) were simulated for a flow velocity of 10m/s and yaw angles 0-20° using OpenFoam based Nabla Flow CFD simulation software. Significant differences were observed by changing and optimizing the cyclist's posture with CdA values ranging from 0,214 to 0,450. Within a position, CdA tends to increase slightly at yaw angles of 5-10° and decrease at higher yaw angles compared to a straight head wind. The results were applied to the Ironman (IM) Hawaii bike course that shows high probability for wind yaw, estimating a constant athlete power output of 300W. The course was cut into 20 distinct segments. Taking the wind probabilities into account, two different models with weighted CdA and average yaw angle CdA were calculated. Firstly, significant time savings by roughly 50min over the course of 180km can be found only by posture optimization. Furthermore, notable time differences of ±2,5% (7min) were observed within the two different models presented in Table 1. The average CdA model generally shows slower bike split predictions due to

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the increase of CdA at moderate yaw angles which appears to be inaccurate over the whole course. The weighted CdA model, on the other hand, considers wind probability for each segment more accurately. Therefore, wind yaw and the use of an appropriate model must be considered for bike split predictions. For future research, a machine learning approach to deduce 3D triangulation for specific cycling positions as input for a CFD study (see Fig 1 (b) and Fig. 1 (c)) can be an insightful tool to simplify the time and cost consuming 3D scanning procedure even if the accuracy is currently not yet satisfactory.

Position	**Weighted CdA**	**Avg CdA**
TT	4:10:10	4:04:36
DB	4:20:32	4:22:28
HD	4:48:14	4:54:43
HH	4:55:10	5:02:55

Table 1: IM Hawaii Bike split model with weighted CdA vs. average CdA simulation, time in hh:mm:ss, power output 300W

As a result this approach shows:

- The drag area for different positions varies by more than a factor of 2 with CdA values ranging from 0.21 to 0.45
- CdA increases at yaw angles of 5-10° and decreases at higher yaw angles
- Variation and probability of yaw angles must be taken into account and lead to an improvement in accuracy of 2.5%
- Significant time savings of 50min over 180km can be found only by posture optimization
- Machine learning approach to determine 3D cyclist geometry shows promising potential to simplify CFD simulations

1. Georgios Pavlakis et al. (2019) Expressive Body Capture: 3D Hands, Face, and Body From a Single Image, Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR).
2. https://nablaflow.no/digital-wind-tunnel

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