Toward a robust and inexpensive method to assess the aerodynamic drag of cyclists

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Context

- **Aerodynamic drag = 80-90% of resistive forces**

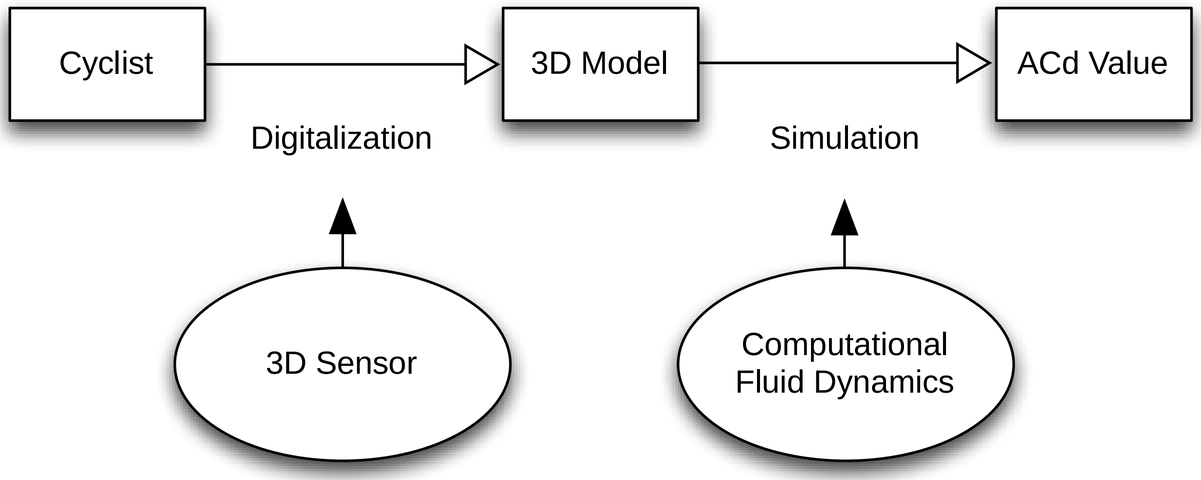
- **Effective Frontal Area (ACd) : $F = 0.5\ ACd\ \rho\ v^2$**
- **ACd should be reduced so must be quantified**

- **Existing Method :**
  - Wind tunnel
  - Dynanometric measurement
  - Deceleration + Linear regression
  - …

A new method: 3D+CFD

- **Recently proposed method :**
  - 2010 : Computational fluid dynamics analysis of cyclist aerodynamics
    Defraeye, T. et al. [1]
  - 2016 : Preliminary study: A new method to assess the effective frontal area of cyclists
    Bouillod, A . et al. [2]

- **Principle :**



3D +CFD : advantages

- **Low operating and equipment costs**
- **Measuring conditions closer to real world**
- **Many experiments are possible :**
  - Simulating different wind conditions
  - Simulating different cyclist speeds
  - Assessing different equipments (helmet,wheel, …)
  - Simulating team pursuit :

    CFD simulations of the aerodynamic drag of two drafting cyclists.

    Blocken et al. (2013) [3]

3D +CFD : limitations

- **Lack of accuracy :**
  - [2] : difference of 10.9 % with the wind tunnel results
  - [2] : difference of 13.1 % with linear regression on track results
  - [3] : difference of 10.5 % with the wind tunnel results
- **Too much differences to be usefull !**
  - We are searching for improvements of ~2-3 %
  - So accuracy has to be better than 1 %

Why this lack of accuracy?

- **Non linearity of aerodynamic :**
  - Acd (bike + cyclist) ≠ Acd (bike) + Acd (cyclist)
  - Our experimental results:
    - Cyclist: Acd = 0.2151 ; Bike: Acd =0.082
    - Bike+Cyclist : Acd = 0.2890 ≠ 0.2971
    - Difference = ~3 %
- **Use of static model :**
  - Only one crankset position
  - But crank position has en effect on Acd
  - Our experimental results:
    - Crank 0° : Acd = 0.24
    - Crank 90° : Acd = 0.2567
    - Difference = ~5 %

How to get further ?

- **Get an experimental set-up closer to real world**
  - Dynamic scene acquisition
  - Free moving bike, allowing residual motions

≠

Images from [2]

How to get further ?

- **Take into account the variability of cyclist speed**
  - ACd depends on speed
  - Our experimental results:
    - Speed 10 m/s : Acd = 0.2629
    - Speed 12.5 m/s : Acd = 0.2645
    - Speed 15 m/s : Acd = 0.2567

- **Take into account the variability of wind conditions**
  - ACd depends on wind
  - Our experimental results:
    - Wind ¾ front : Acd = 0.3893
    - Wind ¾ back : Acd = 0.1556

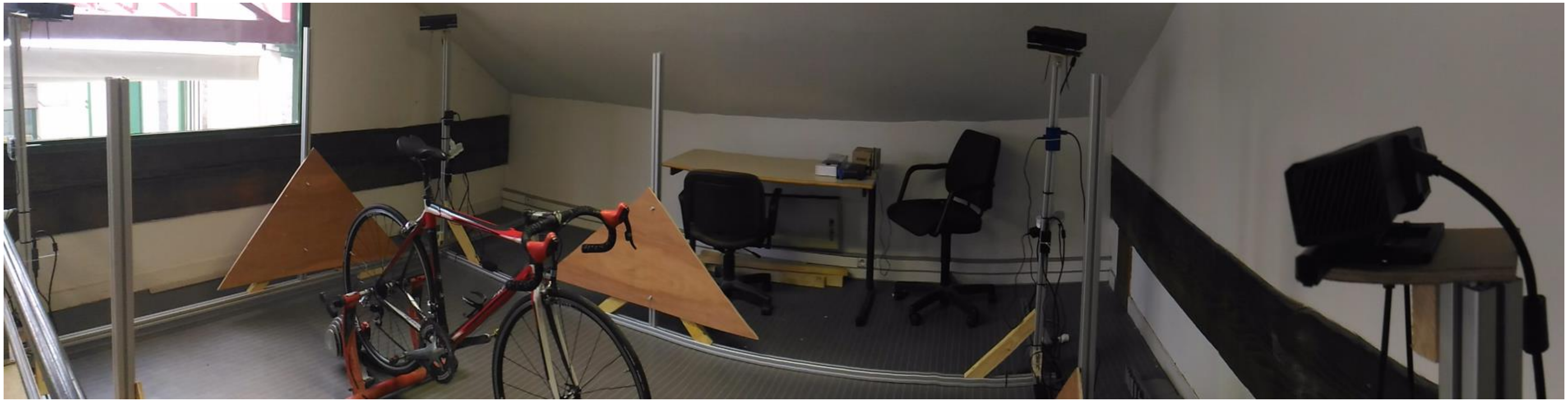
Wind = 5 m/s ; Cyclist = 15 m/s

Proposed improvements

- **Digitalization of the cyclist AND the bike**
- **Digitalization of a full pedalling cycle**
- **Measurament conditions close to real world:**
  - No markers
  - The cyclist is free to move
- **Aggregation of number if simulation:**
  - Composite value of ACd
  - Take into account different speeds and wind conditions

Our methodology (digitalization)

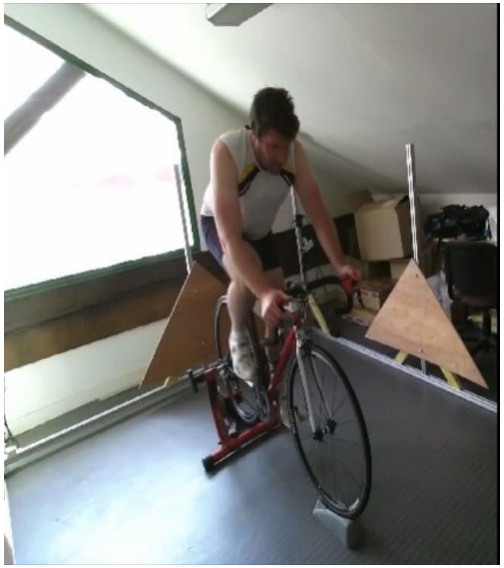
- **4 low-cost RGB-D (color and depth) sensors**
- **No marker**



- **The system will be described in another paper**

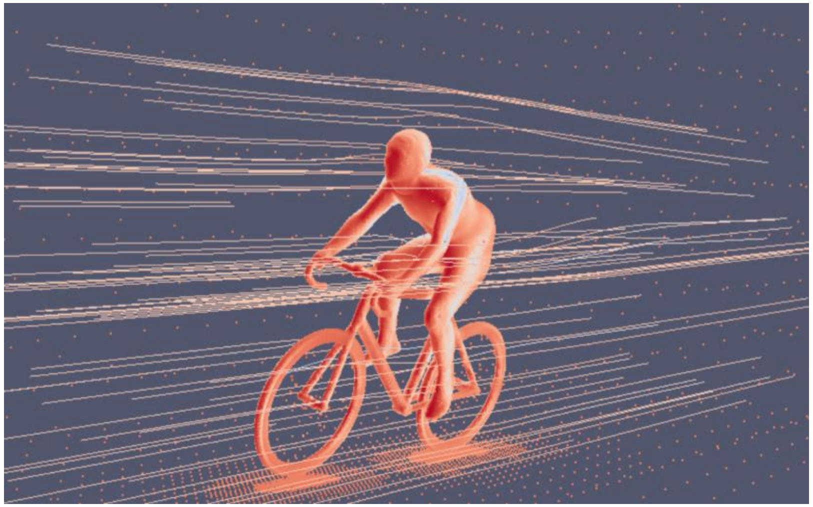
Our methodology (digitalization)

- **Exemple**



Our methodology (CFD)

- **OpenFoam solver**
  - Surface discretized with polyhedral surface mesh
  - k-ω-SST turbulence model
  - Numerical wind tunnel = 3 m x 3 m x 6 m box



Our methodology (Acd computing)

- **Method described in the patent WO2017/012923**

- **Aggregation of many simulations :**
    - Different cyclist speeds
    - Different wind directions
    - Different wind speeds

- **We want to find the best position :**
    - For every particular case
    - Taking into account all the variabilities

Questions ?