Experimental validation of a computer-vision based 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**

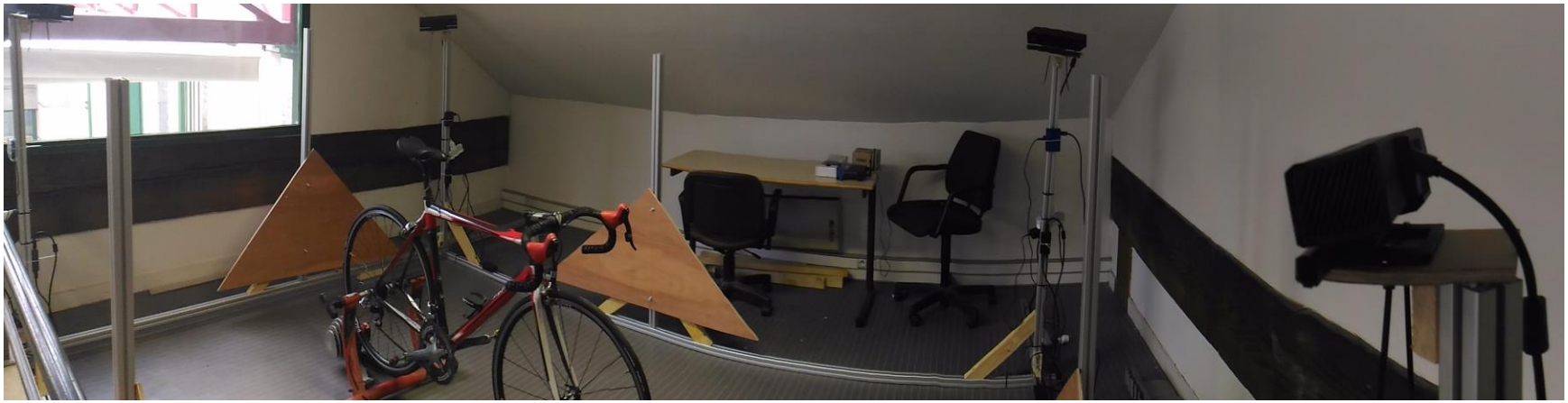
- **Existing Method :**
  - Wind tunnel
  - Dynanometric measurement
  - Deceleration + Linear regression
  - **Recently 3D digitilization + CFD**

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

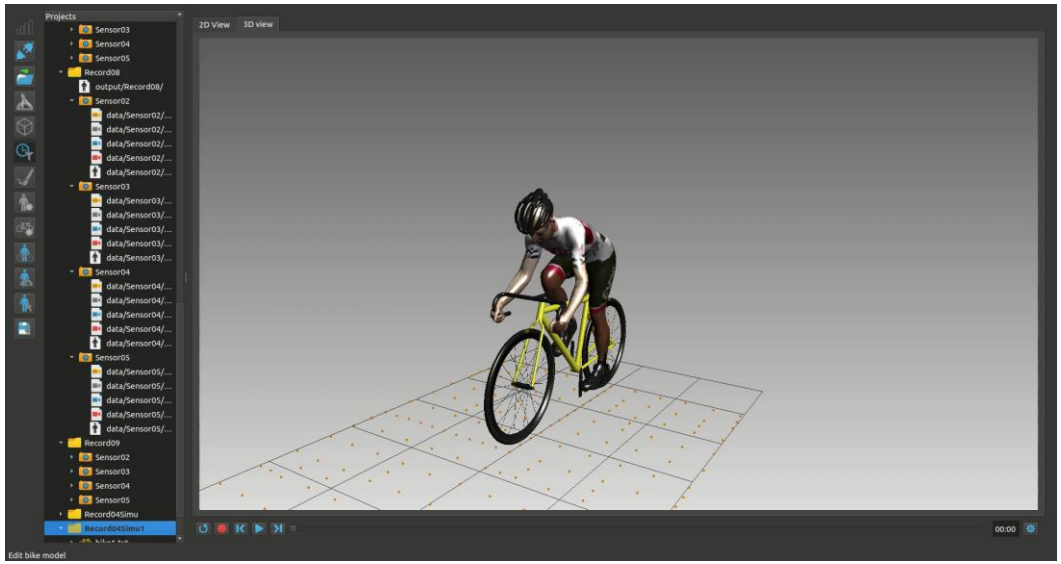
Ergocycle method (1)

- **Set-up :**
  - 4 RGB-D Sensors
  - 4 Nano-computers (slaves)
  - 1 master computer (manage digitalization)
  - calibration patterns on the floor



Ergocycle method (2)

- **Cyclist Digitalization using a Human Body Model :**
  - No pre or post-processing work
  - Model is composed of:
    - Anatomical features
    - Pose features



Ergocycle method (3)

- **OpenFoam solver**
  - Surface discretized with polyhedral surface mesh
  - k-ε turbulence model
  - Numerical wind tunnel = 18 m x 18 m x 54 m box

Experimental data (1)

- **Aero Concept Engineering's facility in Magny-Cours (France)**
  - single return closed-circuit wind tunnel
  - width: 2.3 m, height: 2.2 m, length: 4,75 m
  - 6-components balance (500Hz for 15 seconds)
  - air temperature, wind speed and atmospheric pressure

- **Data processing:**
  - averaging the values given by the balance
  - computing effective frontal area (to compensate for changes in air parameters):

$$AC_d = \frac{2F}{\rho V^2}$$

Experimental data (2)

- **Subjects**

Subject ID	Height (cm)	Weight (kg)	Age
1	177	85	38
2	174	64	18
3	161	53	12

- **Crank angles**
  - 0°
  - 45°
  - 90°
  - 135°

- **Speeds**
  - 30 km/h
  - 40 km/h
  - 50 km/h

- **Static positions**
  - Uprigth position
  - Brake-hoods position
  - Dropped position

Experimental data (3)

- **Experimental conditions**

Mesurement ID	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Position	BH	BH	BH	BH	BH	BH	BH	BH	U	U	U	D	D	D	BH
Crank angle	0	45	90	135	0	45	90	135	135	135	135	135	135	135	135
Wind speed	30	30	30	30	50	50	50	50	30	40	50	30	40	50	40

- **15 measures x 3 athletes = 45 measures**

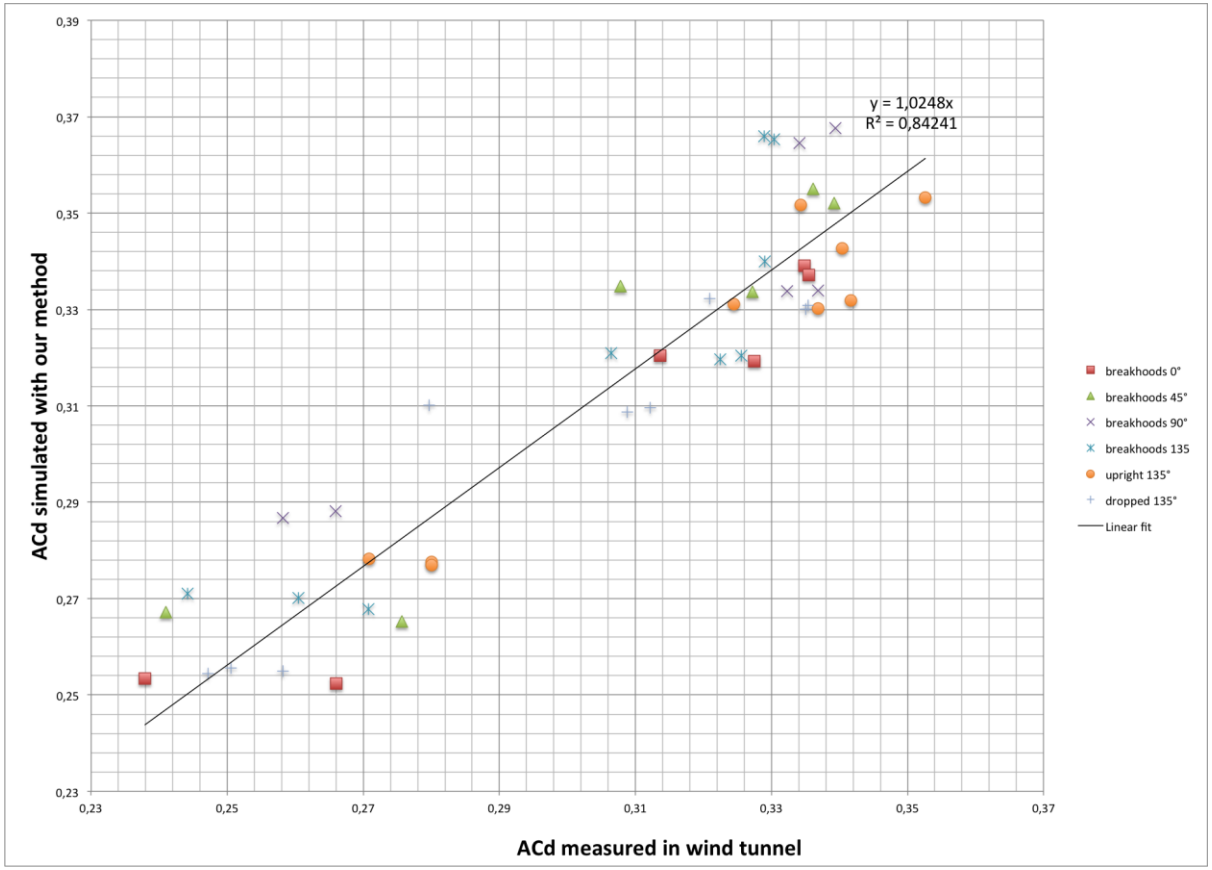
- **We reproduced the same conditions with our system**
  - 3D models
  - CFD simulations
  - Simulated forces -> ACd

Results (1)

- **Comparison wind tunnel / our method**

Correlation = 0,84

Proportionnality = 1,02

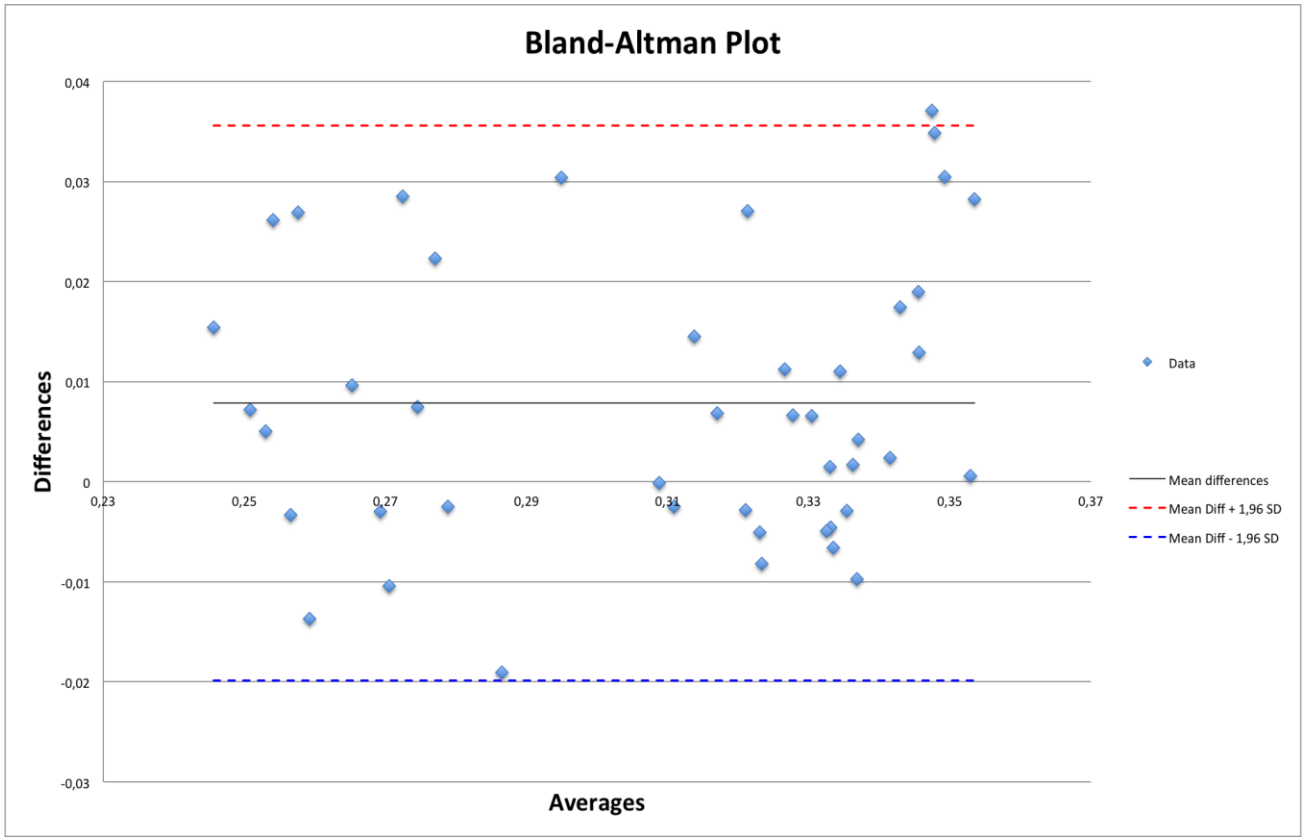


Results (2)

- **Comparison wind tunnel / our method**

Difference statistics :

- Mean = 0,0078
  = 4,1 %
- Std = 0,014
- Max = 11,3 %



Discussion

- **Drag measurement with our method**
  - Good correlation with wind tunnel data
  - Proportionality ≈ 1
  - Weak and non-systematic bias
  - Excellent agreement between measurements

- **Important note**
  - Average difference between measurements ≈ 4%
  - BUT cyclist's inablity to perfectly reproduce position
  - Theorically : differences mean = 0 ; std = 0,011
    in this study : 0,0078 0,014

➔ In reality difference between measurements << 4%

Conclusion

- **A new drag assesment method based on computer vision**
- **Experimental data from wind tunnel**
- **Results**
  - Good correlation between our method and experimental data
  - Excellent agreement
  - Measurements differences << 4%

  ➔ **Validation of our method**

- **Future works**

  Validation for wind coming from different directions

  Validation in real conditions

Questions ?