Digital twins to enhance cycling performance

Terchniques, roadmaps and first results

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Human Scale

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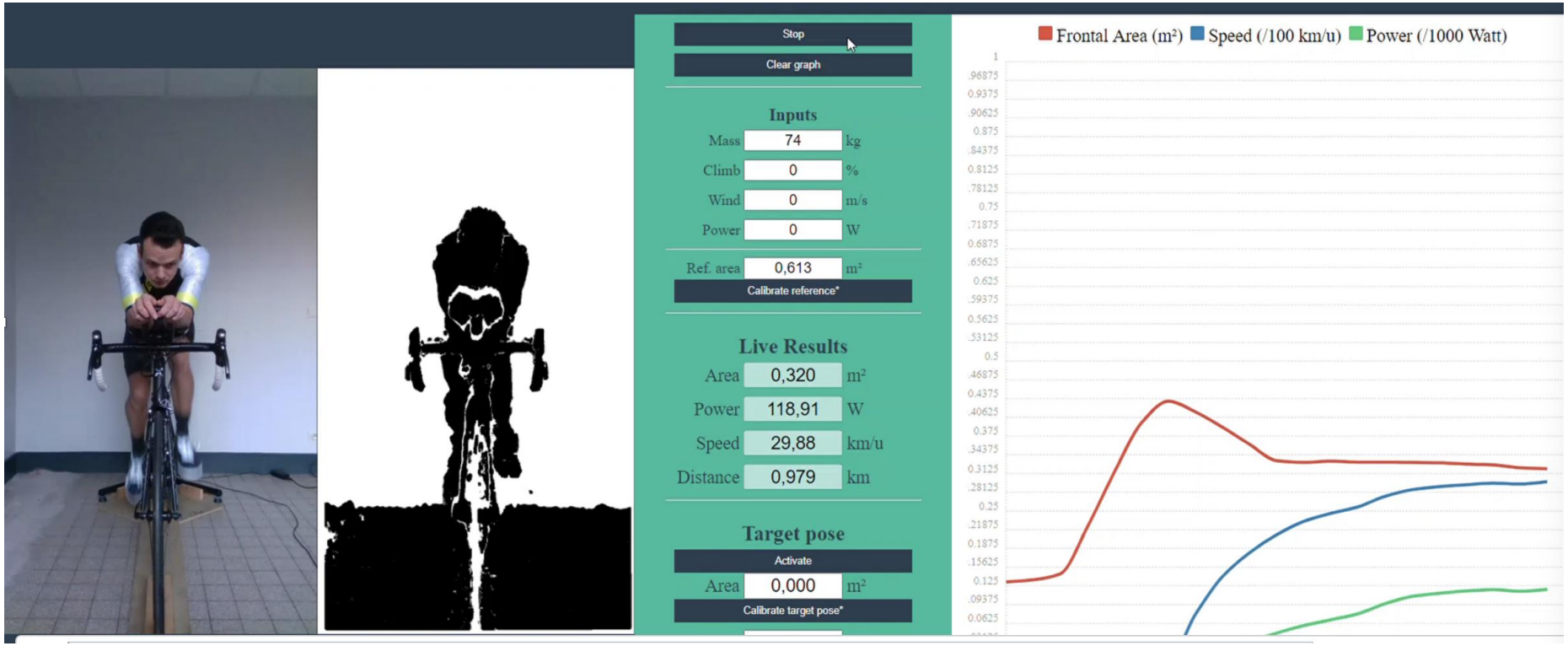
Overview

- First approach: smarttrainer
- Second approach: ultrafast 3D scanning

First approach:

Integrate aerodynamics in a smarttrainer



Rationale

$$P = \frac{1}{2}\rho * C_d * A * (v_{\text{air}})^2 * v_{\text{ground}}$$

$$P(t) = \frac{1}{2}\rho * C_d(t) * A(t) * (v_{\text{air}}(t))^2 * v_{\text{ground}}(t)$$

$$P(t) = \frac{1}{2}\rho * C_d(t) * A(t) * (v_{\text{air}}(t))^2 * v_{\text{ground}}(t)$$

Real-time aero sensor-actuator

Setup

FAAST

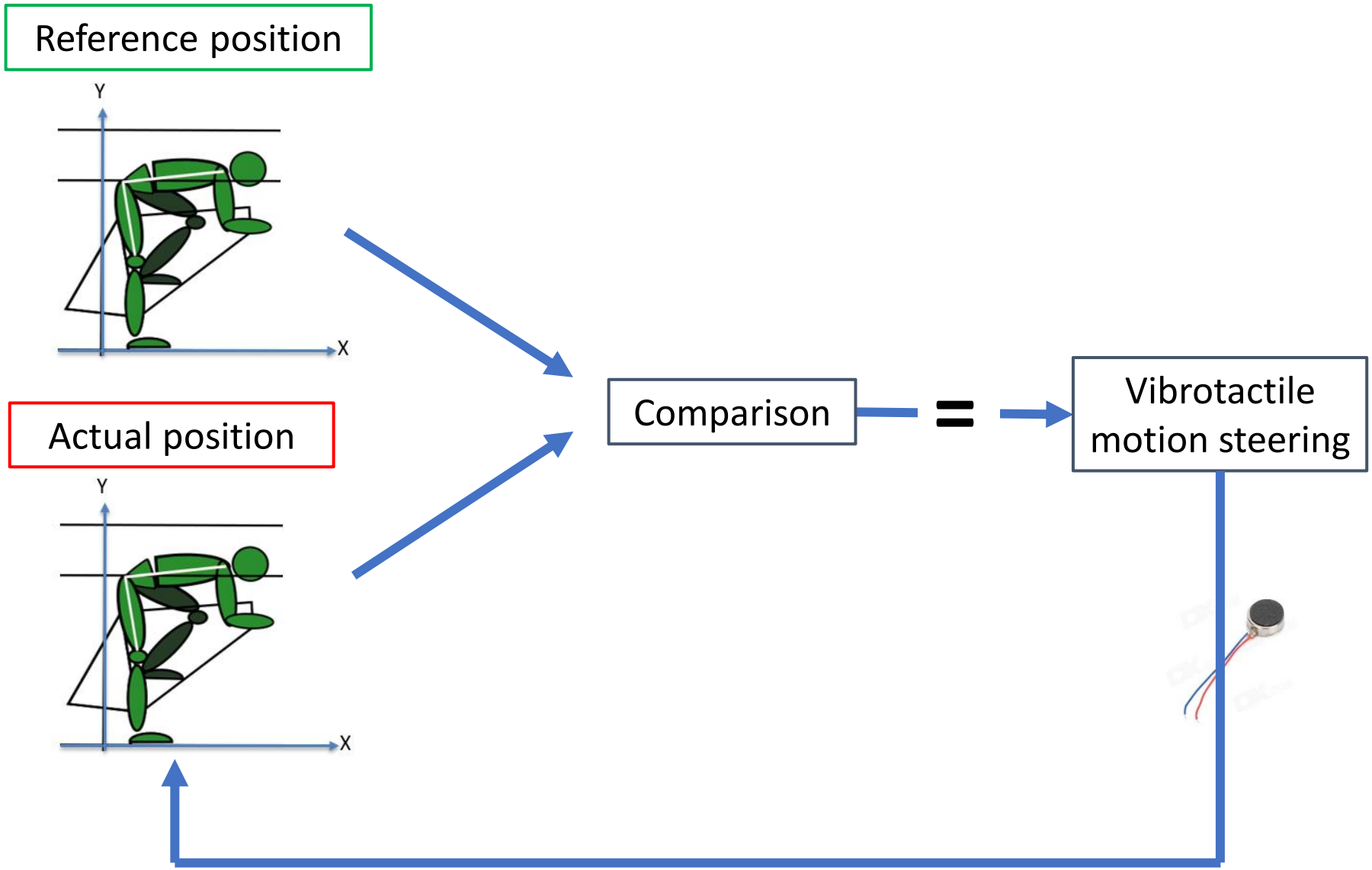
Immersive indoor cycling with outdoor aerodynamics

Discussion

- Fair esports
- Early talent scouting
- Smart bikefit
- Train muscle memory
- **Anticipating on future technologies**
- **Dangerous experiments in safe conditions**

Anticipating on future technologies:

Vibrotactile motion steering



Effect in the lab

With and without motion steering at 50km/h

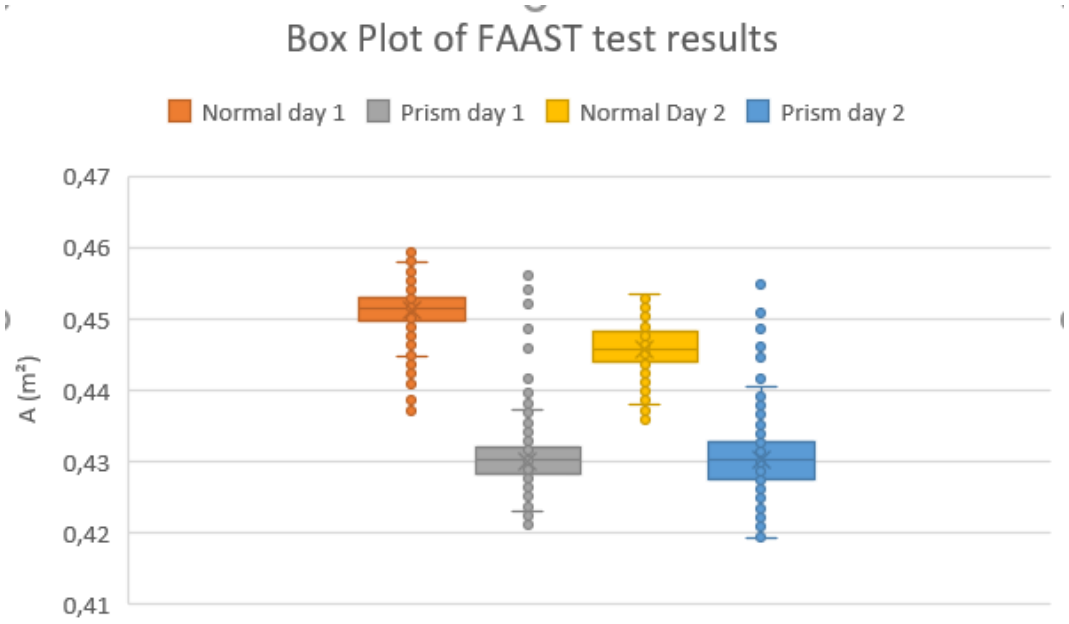
Intervention	Δ frontal area (m^2)	Δ power (W)
1.5% - No	-0.0068	-11.75
3% - No	-0.0046	-8.05

Theoretical effect of ± 20s for 1h

Dangerous experiments in safe conditions

Results:

Gain of 3% confirmed in windtunnel and velodrome



Can we further improve accuracy of aerodynamic simulation?

$$P = \frac{1}{2}\rho * C_d * A * (v_{\text{air}})^2 * v_{\text{ground}}$$

$$P = P\ (v_{\text{ground}}, v_{\text{air}}, \text{pose})$$

Phase 1 $$P = \frac{1}{2}\rho * C_d * A(t) * (v_{\text{air}})^2 * v_{\text{ground}}$$

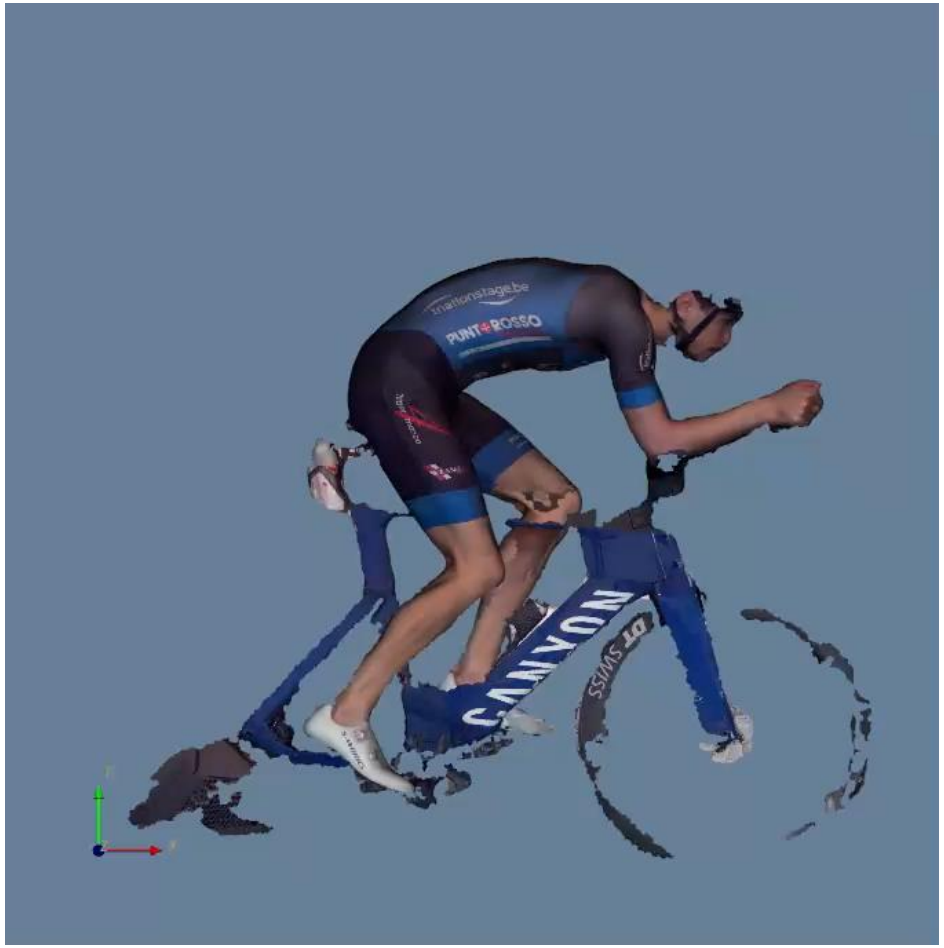
Phase 2 $$P = \frac{1}{2}\rho * C_d(t) * A(t) * (v_{\text{air}})^2 * v_{\text{ground}}$$

Second approach

Ultrafast 3D scanning

Step 1: scan

MOVE 4D



CFD analysis on articulating bodies

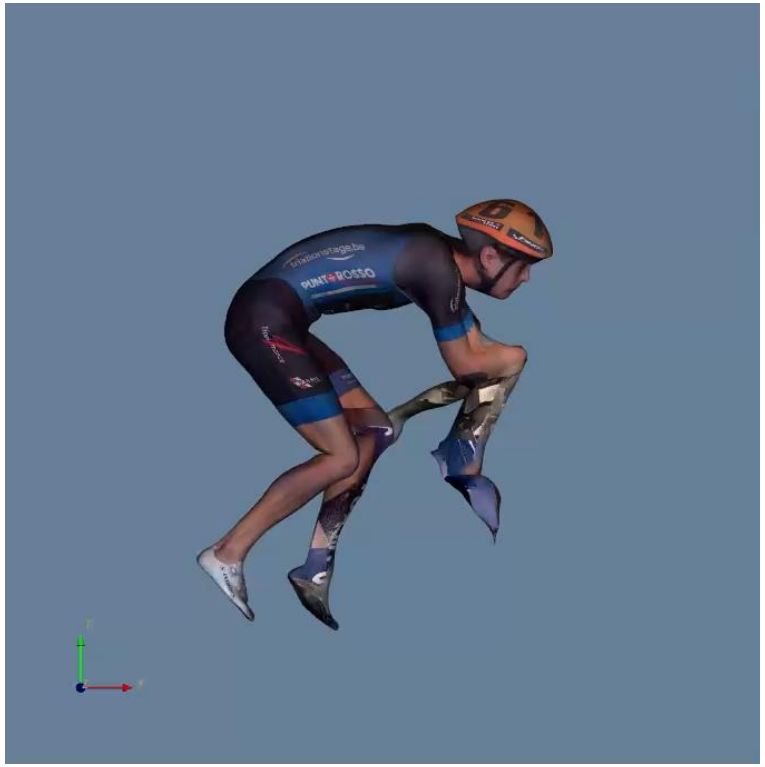
Step 1: 4D scan

Step 2: Make scans watertight

CFD analysis on articulating bodies

Step 1: 4D scan

Step 2: ~~Make watertight~~



CFD analysis on articulating bodies

Step 1: 4D scan

Step 2: Separate subject from bike

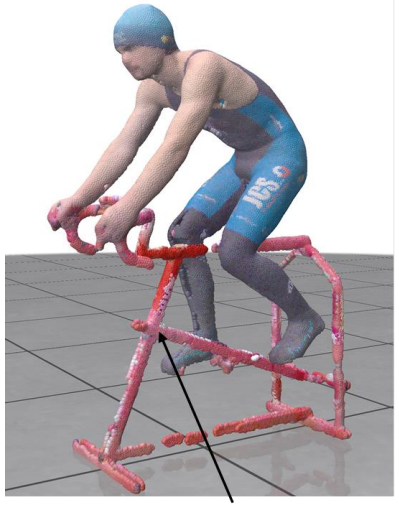
Step 3: Register scan to avatar

Separate subject from bike

Paint it red

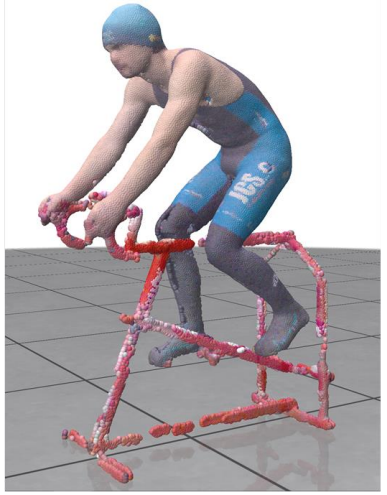
Separate subject from bike

~~Paint it red~~

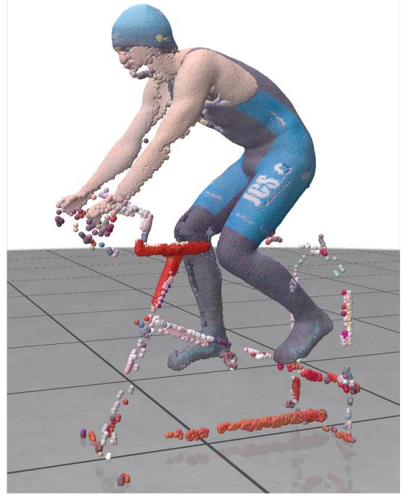


Filtered by

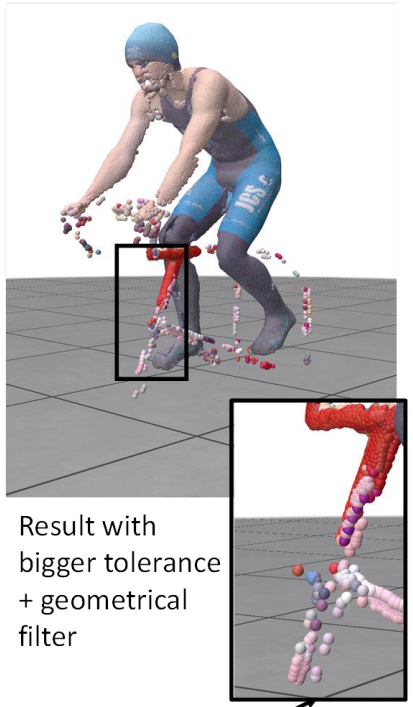
Color in between dark red and white



Result with small tolerance



Result with bigger tolerance



Result with bigger tolerance + geometrical filter

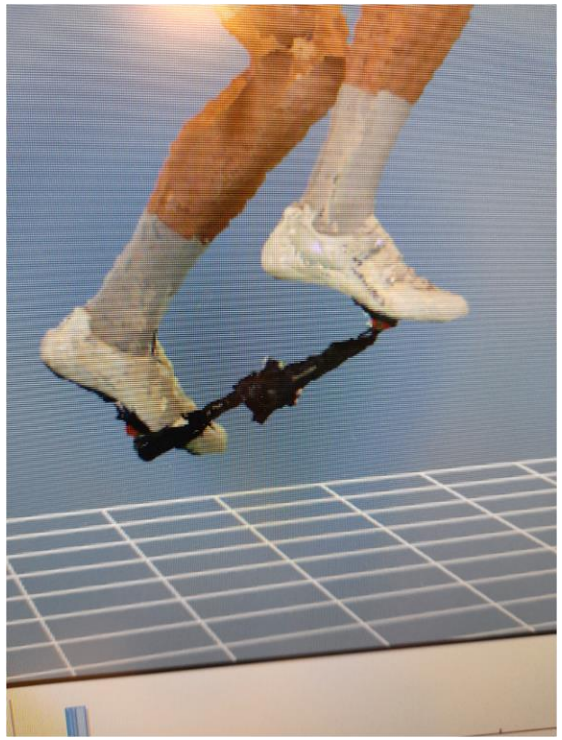
Problem of the color of the bike: from dark red to red including lots of colors

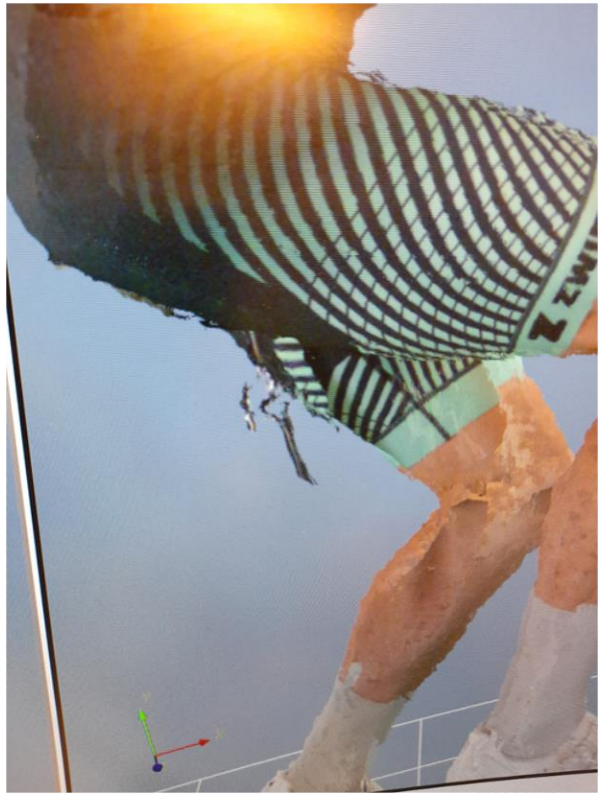
Separate subject from bike

~~Paint it red~~

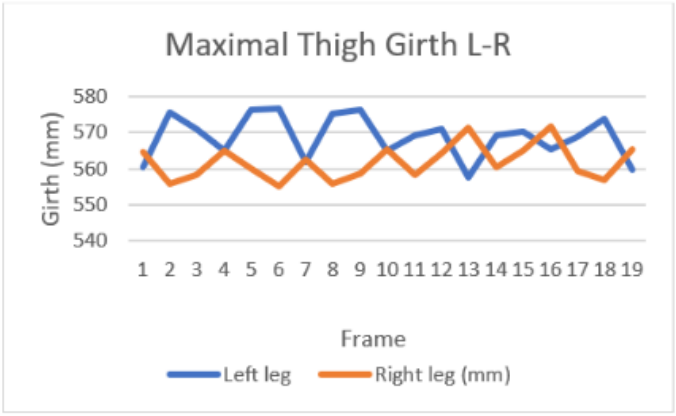
I want it

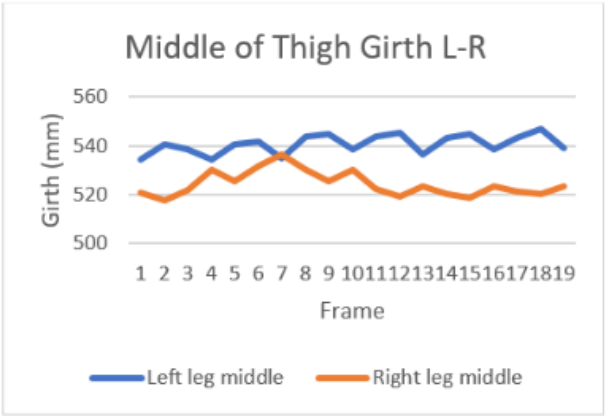
Discussion

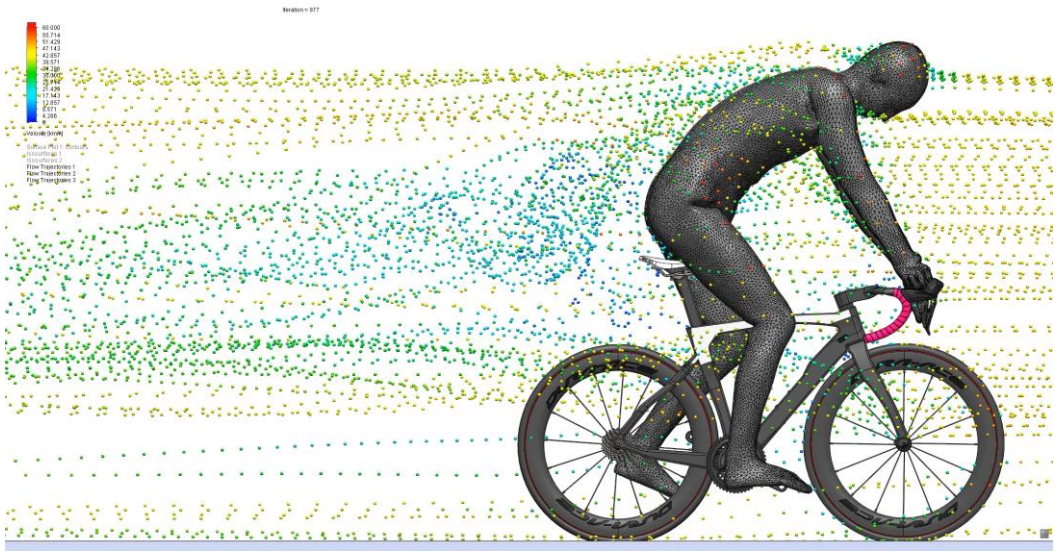




Results


Maximal Thigh Girth L-R
Girth (mm)
580
570
560
550
540
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
Frame
Left leg
Right leg (mm)


Middle of Thigh Girth L-R
Girth (mm)
560
540
520
500
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
Frame
Left leg middle
Right leg middle



Conclusion

- Watertight 3D scan acquired in less than 10 microseconds
- Sequence of 3D scans acquired at 180 frames per second
- 50k points per scan
- In full collor
- Watertight
- Accurate dynamic mesh: correspondence between physical and digital points
- Dynamic anthropometric features
- Way to go for CFD on articulating cyclists

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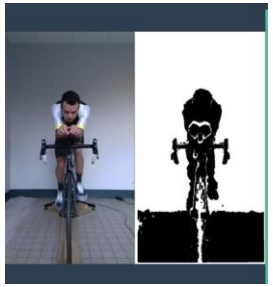

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