Cybathlon 2024 FES race result correction Factor for HunFES

Background

Some teams do not provide enough Wattage measured at the wheel hub to drive the FES bike race. Therefore, a Wattage measurement at the crank is performed with instrumented pedals that involves pressure measurement, which is more sensitive, but less robust/accurate.

The measured Wattage at the pedals is higher than the one measured at the wheel hub. The crank level arm is directy proportional to this and teams use different cranks. Changing the virtual crank length the difference is Wattage between pedal and wheel hub was set to 7.5% (with a tolerance of +-2.5%).

$$\mathrm{cAdv} = \frac{P_{\mathrm{Pedals}}}{P_{\mathrm{wheelHub}}}$$

```
cAdv = 0.075;
```

The virtual crank in the game cannot be reduced below 140mm. Team HunFES is set to this minimum, but measures a Wattage that is around 40% higher than the one on wheel hub.

$$\mathrm{cAdv} = \frac{P_{\mathrm{Pedals,HunFES}}}{P_{\mathrm{wheelHub,HunFES}}}$$

```
cAdv_HF = 0.4;
```

Goal

To let HunFES nevertheless participate despite this advantage, we want to correct their achieved result distance by a punishing factor to make it comparable to other teams.

Limitations

There is no solution we can accurately take the variable acceleration at start or the variable speed on race finish into account properly. We therefore opt for a simple solution working with the variables we can estimate from the game:

- Game Distance x_end [m]
- Average Wattage P_pedals [W]
- Weight of the pilot (virtual bikes no masses)

```
x_endHunFES = 1000 %[m] example value to be corrected
```

```
x_endHunFES = 1000
```

```
P_pedalsHunFES = 32 %[W] example value 32 to be updated after race!
```

```
P_pedalsHunFES = 32
```

```
m_HunFES = 80 %[kg] example value to be updated
```

```
m_HunFES = 80
```

Our simplification applied will be that we only consider steady-state velocity-wattage relationships, but ignore acceleration at start and variable velocity still at race end.

Step 1 - Wattage correction

$$\frac{P_{\text{corrected,HunFES}}}{P_{\text{Pedals,HunFES}}} = \frac{1 + c_{\text{Adv}}}{1 + c_{\text{AdvHF}}} = c_{\text{WattCorrect}}$$

```
c_WattCorrect = (1 + cAdv)/(1+cAdv_HF)
```

```
c_WattCorrect = 0.7679
```

```
P_corrPedalHunFES = c_WattCorrect*P_pedalsHunFES;
```

Step 2 - Calculate steady-state velocities

We use a Model we received from the Indie Velo provider [1]. Using only rolling resitance as a loss. (horizontal ground, no wind, no aerodynamic resistance)

```
Crr = 0.005;
g = 9.81;
F_rolling = m_HunFES*g*Crr;
```

$P_{\text{wheel}} = F_{\text{resist}} \cdot V_{\text{gs}}$, where V_{gs} is the steady state velocity if steadily providing P_{wheel}. We directly use the average Wattage at pedals without drive train losses.

```
v_HunFES = P_pedalsHunFES/F_rolling;
v_corrHunFes = P_corrPedalHunFES/F_rolling;
```

$$\frac{x_{\text{endCorrHunFess}}}{x_{\text{endHunFess}}} = \frac{v_{\text{corrHunFES}}\, t_{\text{end}}}{v_{\text{corrHunFES}}\, t_{\text{end}}} = c_{\text{corrX}}$$

```
c_corrX = v_corrHunFes/v_HunFES
```

```
c_corrX = 0.7679
```

```
x_corrHunFes = c_corrX*x_endHunFES
```

```
x_corrHunFes = 767.8571
```

Conclusion

Only considering Rolling friction as a loss, the steady-state velocity and the Wattage have a linear relationship and the correction factors are the same: $c_{\text{WattCorrect}} = c_{\text{corrX}}$

Therefore, the weight and average wattage achieved during the race of the pilot does not matter and we can just multiply the achieved distance by

```
c_WattCorrect
```

```
c_WattCorrect = 0.7679
```

Bibliography

[1] “An interactive model-based calculator of cycling power vs. speed.” Accessed: Oct. 24, 2024. [Online]. Available: https://www.gribble.org/cycling/power_v_speed.html