Parameter-Space Mining of 2018-2020 Tours de France to Model 2021 Tour de France

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The authors of this paper are part of a research group that has modelled the Tour de France since 2003 [1-7]. The basis of the model are the terrain data obtained from profiles of the 21 race stages. The terrain mesh may be refined by obtaining additional data with software capable of extracting pixel information for published terrain images. A terrain datum consists of the distance biked to that point in the stage and the elevation above sea level at that point. From that information, a sequence of inclined planes may be created [1] to represent each stage. For the 3414.4-km 2021 Tour de France, 1095 terrain data were used, which implies an average mesh size of a little more than 3 km. The model sought to predict the winning time for each stage; it did not model any particular cyclist.

A mass moving on a plane inclined at angle θ to the horizontal is a problem with which any first-year physics student is familiar. The forces acting on the rider-bicycle are: a gravitational force acting down with magnitude mg, where m is the rider-bicycle mass and g = 9.8 m/s^2 is the magnitude of the acceleration due to gravity, a normal force $F_N = mg\cos\theta$ from the road, a forward force from the road that has its origin in the cyclist's power output, $P(\theta)$, rolling resistance of the form $\mu_r F_N$, where $\mu_r = 0.003$, and air drag, exressed as $\frac{1}{2}\rho C_D A v^2$, where ρ is the air density that has exponential dependence on altitude, $C_D A$ is the drag area, and v is the bike's speed relative to the air (variations in weather are not accounted for). The latter two forces act opposite the bike's velocity. Cyclist power output and drag area are given by [4] $P_0 + P_1\theta + P_2\theta^2 + P_3\theta^3$ and $a + b\tanh[c(\theta - d)]$, respectively.

The 2021 Tour de France model was created by mining an eight-dimensional parameter space (P_0, P_1, P_2, P_3, a, b, c, d) using terrain data and actual winning times for the 2018-2020 Tours de France. The optimal solution was obtained when the sum of squares of relative errors was minimized. Table 1 lists the model's predictions with the actual stage-winning times. Fifteen of the 21 stages were predicted to 4.1% or better. Of the six other stages, 9.7% was the largest error. The new model appears to incorporate a slightly-higher-than-average cyclist power output, which seems to be due to the influence of the peloton, where drafting and team help allow for power outputs smaller than during cycling while alone.

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Table 1: **Actual and Predicted Winning Times for 2021 Tour de France**.

Stage	Actual	Predicted	Difference	% Difference
1-F	4h 39′ 05″	4h 36′ 19″	-02′ 46″	-0.99
2-MM	4h 18′ 30″	4h 17′ 14″	-01′ 16″	-0.49
3-F	4h 01′ 28″	4h 07′ 58″	+06′ 30″	+2.69
4-F	3h 20′ 17″	3h 23′ 45″	+03′ 28″	+1.73
5-ITT	0h 32′ 00″	0h 32′ 19″	+00′ 19″	+0.99
6-F	3h 17′ 36″	3h 36′ 46″	+19′ 10″	+9.70
7-MM	5h 28′ 20″	5h 47′ 52″	+19′ 32″	+5.95
8-M	3h 54′ 41″	3h 58′ 34″	+03′ 53″	+1.65
9-M	4h 26′ 43″	4h 07′ 31″	-19′ 12″	-7.20
10-F	4h 14′ 07″	4h 16′ 57″	+02′ 50″	+1.11
11-M	5h 17′ 43″	5h 16′ 02″	-01′ 41″	-0.53
12-F	3h 22′ 12″	3h 39′ 30″	+17′ 18″	+8.56
13-F	5h 04′ 29″	4h 59′ 08″	-05′ 21″	-1.76
14-MM	4h 16′ 16″	4h 23′ 19″	+07′ 03″	+2.75
15-M	5h 12′ 06″	4h 54′ 28″	-17′ 38″	-5.65
16-MM	4h 01′ 59″	3h 56′ 52″	-05′ 07″	-2.11
17-M	5h 03′ 31″	4h 58′ 23″	-05′ 08″	-1.69
18-M	3h 33′ 45″	3h 40′ 36″	+06′ 51″	+3.20
19-F	4h 19′ 17″	4h 37′ 30″	+18′ 13″	+7.03
20-ITT	0h 35′ 53″	0h 36′ 40″	+00′ 47″	+2.18
21-F	2h 39′ 37″	2h 33′ 04″	-06′ 33″	-4.10
TOTAL	81h 39′ 35″	82h 20′ 47″	+41′ 12″	+0.84

A plethora of other comments and more quantitative details will be presented during the conference talk associated with this short paper.

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