ISSN 2618-1576 Vol. 4, Issue 3: 38-41, DOI: 10.25236/FSR.2022.040308

Simulation and Optimization Model of Bicycle Time Trial Based on Genetic Algorithm

Yizhi Zhou, Yuhang Yao, Jiabao Yang

College of Mechanical and Automotive Engineering, South China University of Technology, Guangzhou, Guangdong, 510461, China

Abstract: *We have established a simulation optimization model of bicycle time trial based on genetic algorithm. By using the algorithm, we can not only get the best force of different sections, but also get personalized analysis of different players. These two sets of data can directly help us find the shortest time for a particular rider to finish a particular race. In this paper, we expanded the model biased towards the six-person team time trial, and successfully combined the genetic algorithm to find out the best time duration and the best order for everyone in the team to break the wind. First of all, we built a basic physical simulation model of bicycle individual time trial. The two resistances can be obtained by the basic laws of physics. Then we consider different terrain factors. Based on this, we also built the corresponding topographic map in combination with the actual road conditions. Finally, we consider the physical strength change of the players, and establish a dynamic physical strength change model combined with related papers. After building the basic physical model, we first need to consider the riding ability of a rider. In order to quantitatively describe how much power players should use in different places, we introduce the road cognition coefficient and terrain difficulty degree. Therefore, an optimal power table of a specific rider for a specific track is obtained.*

Keywords: *Riding simulation; Cognitive coefficient; Genetic algorithm; Optimal force curve*

1. Introduction

There are many types of bicycle road races including a criterium, a team time trial, and an individual time trial. A cyclist's chance of success can vary for these contests depending on the type of event, the course, and the cyclist's abilities. In an individual time trial, each individual cyclist is expected to ride a fixed course alone, and the winner is the cyclist who does so in the least amount of time.

An individual cyclist can produce different levels of power for different lengths of time, and the amount of power and how long a given amount of power a cyclist can produce varies greatly between cyclists. A cyclist's power curve indicates how long a cyclist can produce a given amount of power. In other words, for a particular length of time the power curve provides the maximum power a cyclist can maintain for that given time. Generally, the more power a cyclist produces, the less time the cyclist can maintain that power before having to reduce the amount of power and recover. A cyclist may choose to briefly exceed the limits on their power curve, but the cyclist then requires extra time at a lower power level to recover. Moreover, a cyclist's power output in the past matters, and cyclists are increasingly fatigued as a race progresses. Cyclists are always looking to minimize the time required to cover a given distance. Given a particular cyclist's capability according to that cyclist's power curve, how should that cyclist apply power while traversing a given time trial course? Additionally, many types of cyclists may participate in an individual time trial, such as a time trial specialist, a climber, a sprinter, a rouleur, or a puncheur, and each type of cyclist has a distinct power curve.

2. Model

In combination with the power curve of the defined rider and the road conditions of the track, we use genetic algorithm to get the cognitive coefficient of the track, so as to calculate the power that each rider should use in each period. After subtracting the resistance power, the actual power is used to obtain the instantaneous speed and acceleration of the rider. When the rider's position is updated, the track cognitive coefficient and physical recovery are updated, and the cycle repeats until the end of the race.

ISSN 2618-1576 Vol. 4, Issue 3: 38-41, DOI: 10.25236/FSR.2022.040308

2.1. Track loss power

The power loss on the track is mainly divided into the resistance caused by air resistance and the weight of people and vehicles on the uphill and the power generated by the thrust aid caused by the downhill. Meanwhile, according to our calculation, the influence of friction resistance on the final speed is less than 0.86%, so friction resistance will not be mentioned in the demonstration of obstacles. The power loss caused by the weight of people and vehicles is described by the following formula:

$$\mathrm{P1}=\mathrm{Mg} * \mathrm{v} * \sin\theta / \mathrm{u} \tag{1}$$

Where V is the instantaneous speed of the rider, Mg is the total weight of the human cars, θ is the inclination Angle of the track, and is equal to Arc κ (we defined and introduced κ in detail in 3.2.3) with values ranging from (-π/2 to π/2). We define the parameter u as the transmission efficiency of bicycle, and u=0.85. The power loss can be positive or negative with different values of θ.

$$\mathrm{P2} = \mathrm{r} * \mathrm{v}^3 \tag{2}$$

Where r is the air resistance coefficient and V is the instantaneous speed of the rider.

We define the calculation formula of track loss power as follows:

$$\mathrm{P}^{g}=\mathrm{P1}+\mathrm{P2} \tag{3}$$

2.2. Physical recovery model

2.2.1. Physical force change model description

We assume that the FTP power of the rider is Pō, and the physical strength of each rider is defined as Ɽ. The following formula is used to describe the physical strength consumption and recovery:

$$\mathrm{Ɽ} = 1 - \int_0^t (i - j)dt \tag{4}$$

Where, parameter I is the instantaneous energy consumption rate, and parameter j is the instantaneous recovery rate.

2.2.2. Physical exertion function

Due to the differences among people, we cannot express it with a unified function, but we can improve the rider power graph so that it can reflect the rider's physical energy consumption per second at a specific power. Take the improved time trial expert power graph as an example.

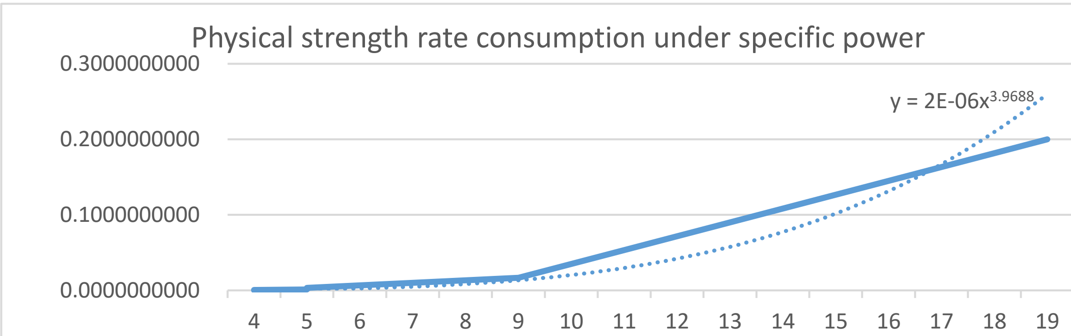

Figure 1: Physical strength rate consumption under specific power

Where the ordinate is the reciprocal of the time the rider can maintain a specific power, that is, the percentage of the rider's physical expenditure per second of a specific power, and the ordinate is the power the rider wants to maintain. So we have a complete model of physical force change.

2.2.3. Track condition and track cognition coefficient

We mainly selected two parameters of the track as the research object, namely, the steepness of the track (the track slope) and the sharp turn degree.

When a rider races, he should make decisions based on the terrain ahead. If the front is a high mountain, it is necessary to maintain or restore the strength of the mountain in preparation for the uphill, if the front is a plain, there is no need to hold the strength of the rider, just sprint. We asked the rider to keep an eye on the road conditions within a kilometer ahead of him, and introduced formulas to describe

ISSN 2618-1576 Vol. 4, Issue 3: 38-41, DOI: 10.25236/FSR.2022.040308

the road conditions for a kilometer ahead of the track.

$$M=\int_{x}^{x+1000} \kappa dl \tag{5}$$

Where x is the horizontal coordinate of the current position of the rider in meters. We normalized M to M^r, and divided all the 1,000-meter sections in front into the following three categories:

When $M^r \in [0,1]$, The 1,000-meter section ahead is "plain section". When $M^r \in [1,2]$, The 1,000-meter section ahead is "Semi-plain Section". When $M^r \in [2,\infty)$, The 1,000-meter section ahead is "steep". We assign the road cognitive coefficient ƀ to each road section, that is, the road cognitive coefficient ƀ is actually a three-segment constant function on the interval $[0,\infty)$.

In order to obtain the most perfect road cognition coefficient ƀ, we first give the functional relationship between it and the rider power P:

$$P=\text{ƀ}_a M^r(r+0.5) \tag{6}$$

Where, the subscript $_a$ represents ƀ allocated by different sections, and subscript a can take the value of (1,2,3); Ɍ is the rider remaining strength rate of the interval $\in[-0.1,0.9]$ proposed in the previous section. According to this function, we can get the instantaneous power of a rider, and then calculate the instantaneous speed and acceleration of a rider, so as to figure out the race time of a rider.

3. Conclusion

Given the initial three ƀ values, we take the three B values as "genetic genes" and set the mutation frequency to find the optimal solution of B. In order to determine the optimal solution of each b, we will take the bottom of the consumption of the whole time as fitness, and call the above build time calculation function as a fitness calculation formula, through genetic algorithm after one hundred and thirty generations iterative calculus, there was a obvious stable solution in 31 generation values, the following screen for genetic algorithm calculation, Male generalists complete the race on time with respect to the results of each generation.

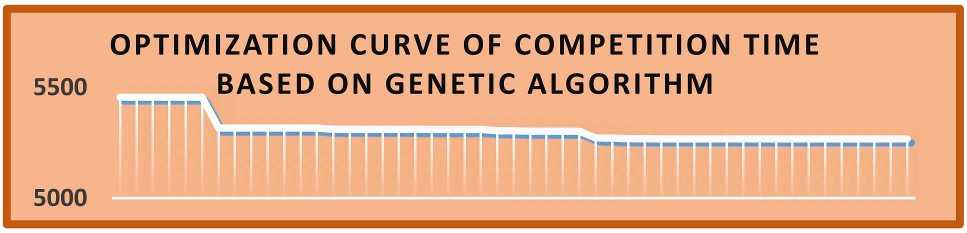

Figure 2: Optimization curve of competition time based on genetic algorithm

Find the road cognition coefficient tending to be stable ƀ, and the value ƀ is the coefficient value that can make the rider's time on the track the shortest.

After the genetic algorithm, we finally get ƀ values as follows:

Table 1: Specific value of optimum coefficient ƀ

b1, b2, b3	**Male generalists**	**Male endurance athlete**	**Female generalists**	**Female endurance athlete**
Belgium	**613.8, 70.3, 40.1**	**706, 79.6, 45.5**	**354.5, 41.5, 26.7**	**415.8, 64, 35.4**
Tokyo	**1770.6 54,6, 297.6**	**1867.2, 17.74 ,26.8**	**1357.1, 273.1, 276.8**	**1240.0, 45.5 ,152.1**
Self-created track	**2374, 314, 249**	**2035, 355, 217**	**1487.6, 293.37, 275.2**	**962.1, 167, 43.0**

In order to analyze the sensitivity of road cognition coefficient, the following chart was drawn. To facilitate the control of variables, we only change one of the three ƀ at a time, and different ƀ corresponds to different types of sections.

Among them, ƀ1 is plain section, ƀ2 is semi-plain section and ƀ3 is steep section. Where, the abscissa is the offset of ƀ, and the ordinate is the ratio of the shortest completion time to the original time.

References

[1] DING YUAN. Analysis and Research on Pedal Frequency of Elite Male Short Distance Track Cyclists in Tianjin [D]. Tianjin Institute of Physical Education, 2021.

ISSN 2618-1576 Vol. 4, Issue 3: 38-41, DOI: 10.25236/FSR.2022.040308

[2] QIAO Jie. Application of Power-Maintenance time curve and critical Power in predicting Cycling Performance [J]. Sports Research, 201, 42(03): 99-104.
[3] Ren Xuyan. Study on the effect of Different Water Bath therapy on fatigue recovery of College Students after power cycling exercise [D]. Capital institute of physical education, 2020. DOI: 10.27340/, dc nki.Gstxy.2020.000072.
[4] Ren Xuyan. Study on the effect of Different Water Bath therapy on fatigue recovery of College Students after power cycling exercise [D]. Capital institute of physical education, 2020. DOI: 10.27340/, dc nki. Gstxy. 2020.000072.
[5] Xi Yugeng, Chai Tianyou, Yun Weimin. Control Theory & Applications, 1996(06): 697-708.