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Solution of Speed Policy Model Based on Genetic Algorithm

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Abstract: *Cycling Road races are divided into standard time trials, team time trials and individual time trials, which pose a great challenge to the physical fitness of cyclists. In this paper, the power curve model and speed adjustment strategy model are established, and the genetic algorithm method is used to formulate competition strategies for different tracks and different players. The research on this issue can provide guidance for cyclists and help them achieve better results.In order to determine the relationship between the driver's position on the track and the driver's strength, this paper establishes a speed adjustment strategy model according to the force analysis. It is essentially a single-objective optimization model. Combining these two models provides runners with instruction in road cycling competitions.In this paper, the genetic algorithm is used to solve the model, and comprehensively considers other factors such as weather and player psychology.*

Keywords: *Power curve; Linear regression; Single-objective optimization; Genetic algorithm*

1. Introduction

1.1. Background

Cycling road racing refers to sports that use bicycles as tools to compete for riding speed. In 1896 the first Olympic Games was listed as an official competition. The International Cycling Union was established in 1900. Since then, it has successively held the World Cycling Championship (held once a year), the World Peace Parade (a multi-day race with a total of more than 2,000 kilometers around Berlin, Warsaw, and Prague), and the Tour de France (around 1 week 3966km multi-day race in France).

Bicycle road races are divided into standard time trials, team time trials and individual time trials. It poses a great challenge to the physical fitness of road racers. Players need to allocate their physical fitness reasonably in different competitions in order to achieve better results.

2. Models Establishment

2.1. Model of Power Curve

Riders can put out different levels of power at different times, and this characteristic varies from person to person. A rider's power curve represents the amount of time he or she can produce a given power, which means the maximum amount of power a rider can sustain over a specific period of time. The more power a rider puts out, the less time he has before he is forced to reduce power and recover.

By studying the lactic acid accumulation of athletes, it is found that there is a critical power (CP) for muscle work, and the part exceeding the critical power has the following functional relationship with the exercise time:

$$t = \frac{AWC}{P - CP} + K$$

t represents time. AWC represents work done at critical power P represents output power. CP represents critical power. K represents peak power coefficient. The expression for K is:K means 1s peak power.

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2.2. Power-based speed regulation model

Since the micro perspective track is too complicated and the situation is too changeable, we choose to process the entire track from a macro perspective. The macro track is not affected by the actual sequence position. By merging the tracks of the same attribute, a simplified macro track that can be easily brought into the model is obtained. In order to solve the model, the following reasonable assumptions are made:

From a macro perspective, the entire track is divided into several sections according to its characteristics. Each track has its own attributes, such as slope, friction coefficient, etc. The attributes in the same track are the same, and the speed is regarded as constant.

According to the power curves of the two types of players in Model of Power Curve, we build a further mathematical model to provide different strategies for different road sections, mainly by setting the speed of each section for the players to guide the players

$$P_{gi} = Mg\sin\theta v_i$$

M Total weight of athlete and bicycle; θ Road slope; v_i The speed of the runner on the i attribute track; From the Bernoulli equation of fluid mechanics, we get the formula:

$$P_{CWi} = \frac{1}{2} C_w \rho A {v_i}^2$$

P_{CWi} The power of the players to overcome the air resistance on the i-attribute track; C_w Air Resistance Coefficient (Drag Coefficient); ρ Air density; A Projected area of the frontal plane of cyclists and athletes;

$$P_i = P_{gi} + P_{CWi} + p_i$$

P_i The actual power of the player on the i-attribute track; P_{gi} The power of the player to work against the gravitational potential energy on the i-attribute track p_i The power of a competitor to overcome other resistances on the i-attribute track, including overcoming the static friction and dynamic friction between the tire and the ground, the frictional force for driving the bicycle, and the inertial force related to bicycle acceleration, etc.

$$\sum_i^n (P_i - CP) x_i / v_i \le W$$

CP Critical power, explained above, can be derived from power curve; W Athlete's anaerobic energy reserve;

$$\sum_i^n x_i = X$$

X Total track distance; x_i the total length of the i attribute track;

Combining the above 5 equations, we build a single-objective optimization model, which we call the Power-based speed regulation model:

$$\begin{gathered} P_i = P_{gi} + P_{CWi} + p_i \\ P_{gi} = Mg\sin\theta v_i \\ P_{CWi} = \frac{1}{2} C_w \rho A {v_i}^2 \\ \sum_i^n (P_i - CP) x_i / v_i \le W \\ \sum_i^n x_i = X \end{gathered}$$

This model will be fine-tuned according to the different tasks that follow.

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3. Analysis

3.1. Rides' Power Curves

Considering the different power characteristics of different riders in individual time trials, we conducted regression analysis on TTS and Rouleur. We checked the FTP test data of some cyclists based on UCI statistics, and performed regression analysis on four data of different types of cyclists, and obtained the following four equations:

$$P = \frac{314.3}{t+24.27} + 3.833$$
$$P = \frac{714.5}{t+59.86} + 4.226$$

$$P = \frac{301.9}{t+27.14} + 2.302$$
$$P = \frac{426.4}{t+41.68} + 4.001$$

In order to verify the data, we find the following table on the website.

Table 1: General Athlete of Road race bike power test comparison table (Part)

	Men				Women			
Time	5 s	1 min	5 min	FT	5 s	1 min	5 min	FT
Times_Trial_Specialst	15.07	7.59	4.70	4.18	11.66	5.57	3.09	2.40
Rouleur	15.07	10.24	5.74	4.71	14.03	8.47	5.22	4.21

Let's draw these curves.

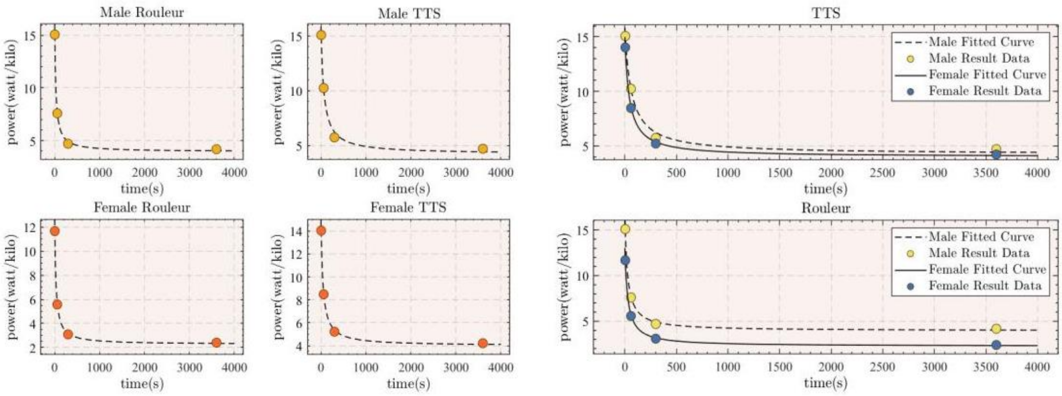

Figure 1: Fitted Curve of Rouleur and TTS

Obviously, the result data falls on the regression curve, and the data fitting result is better. It can be seen from the figure that as the player's output power increases, the maintenance time will become smaller and smaller, which is in line with common sense. Comparing several pictures, we found that the TTS can burst out more power than the Rouleur, but in long-distance riding, the curve of the Rouleur drops slowly, which shows that the Rouleur has better endurance near the critical power. This is more evident in the comparison of female riders.

3.2. Self-created Track

Our model is not set in stone. We can set the number of attributes by specifying the range of attributes according to our needs, that is, to set the number of road types in the same track. Then according to the player information, the model is adjusted by using the power curves of different players solved in TASK1, so that the model can be suitable for any type of players and provide players with different speed strategies. We obtained more detailed track information through the network and the program that crawled the data.

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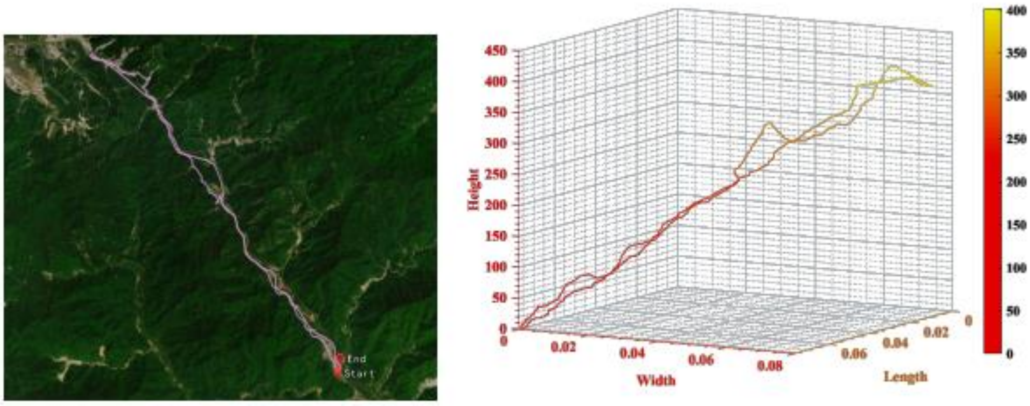

Figure 2: Topographic Map & Spatial 3D Map

We designed self-created track, as shown in the following figure: The self-made track is constructed by considering the actual terrain. It is a closed-loop track. The total distance of the men's race is about 47km, or two laps, and the total distance of the women's race is about 23.5km, or one lap. Obviously, the ups and downs of the homemade track are much more complicated than the previous ones, so we make the following assumptions:

The self-made track has six attributes, namely straight, corner, uphill, steep uphill, downhill, steep downhill.

After the model is solved, the speed strategies for the four players are obtained.

Since our self-created track has not hosted any kind of cycling competition, we lacked a reference and we chose to compare the average speed of the runners to the average speed of other races.

Table 2: Speed strategy for different wind resistance

Gender	TYPE	Straight (m/s)	Corner (m/s)	Uphill (m/s)	Big Uphill (m/s)	Downhill (m/s)	Big Downhill (m/s)	Total time	Average speed (m/s)
MALE	Rouleur	12.11	10.90	5.28	3.32	20.10	24.75	1:12:00	10.88
	TTS	13.00	11.70	6.48	4.05	20.57	25.08	1:04:21	12.17
FEMALE	Rouleur	10.02	9.02	3.89	2.01	18.67	23.41	0:47:30	8.25
	TTS	12.62	11.36	6.17	4.38	19.89	24.25	0:32:25	12.08

3.3. Weather Effects

3.3.1. Model correction

The constraints of the model in this paper are closely related to the formula for calculating the resistance. In TASK 2, although we have considered the influence of air resistance on the athlete's power, we have not considered the influence of the wind. By modifying the formula for solving the real-time output power of the athlete, the model can be reasonably adjusted. Modify the formula for calculating air resistance in the TASK 2 model to the following formula:

$$P_{CWi} = \frac{1}{2} C_w \rho A \left(v_i + v_w\right)^2$$

v_w is the wind speed, positive when headwind and negative when tailwind.

By consulting relevant information, we add soft wind of wind level 1 to the model, that is, wind with a wind speed between 0.3m/s and 1.5m/s, and introduce two cases of tailwind and headwind. A modified model was chosen here for the Tokyo Men's Road Time Trial to see how the speed strategy changes when the effect of wind is taken into account. The result is as follows: It can be observed that in

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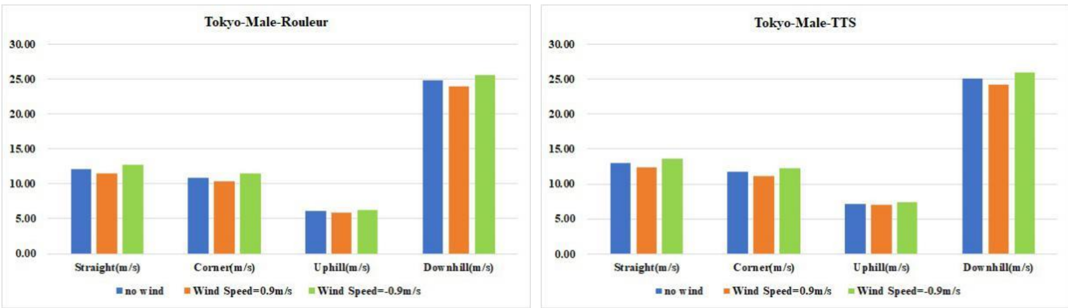

Figure 3: Speed strategies of two types of players facing different wind speeds (The wind speed is positive when headwind and negative when tailwind.)

The headwind condition, the speed is lower than the no-wind condition. In the case of tailwind, the speed is higher than that of no wind. Consistent with common sense, it proves the reliability of the model. We conducted sensitivity analysis on the model, and after calculation, the sensitivity was lower than 5%, which proved that the model is very stable.

At the same time, taking into account the wind, our model can add more road attributes, and can also assign different wind speeds to tracks with different attributes to better fit the actual track conditions and formulate more reasonable speed strategies for athletes.

Table 3: Speed strategy for different wind resistance conditions (Male)

TYPE	Wind Speed	Straight	Corner	Uphill	Downhill	Total time
Rouleur	0	12.08	10.87	6.09	24.75	1:06:22
Rouleur	0.9	11.49	10.34	5.89	23.9	1:09:19
Rouleur	-0.9	12.69	11.42	6.25	25.6	1:03:41
TTS	0	13.04	11.73	7.13	25.08	1:00:18
TTS	0.9	12.41	11.17	6.96	24.24	1:02:47
TTS	-0.9	13.61	12.25	7.43	25.92	0:57:50

4. Evaluation

Model validation has been implemented in each section of the above modeling. Here, we do the sensitivity analysis and assess the strengths, weaknesses.

We have discussed the sensitivity of weather and off-target in TASK3 and TASK4, and the sensitivity is lower than 5%. It can be seen that our model is very stable. The specific discussion has already appeared in the above, and will not be repeated here.

4.1. Strengths and Weaknesses

4.1.1. Strengths

(1) The model constraint basis facilitates the players to make use of their own energy reasonably, and can modify the model according to the actual situation of the track, player ability and weather conditions, so as to obtain a more reasonable speed strategy.

(2) Planning speed strategies from a macro perspective can avoid making difficult decisions in variable situations. With the map data, we can get the formula of track position, driver strength and recommended speed to give more intuitive guidance for the players.

4.1.2. Weaknesses

(1) In order to adjust the player strategy from a macro point of view, the model has limited consideration for acceleration. Solution: Modify the constraints as needed, by increasing several different intermediate velocities between the two attribute velocities. The intermediate velocity lies between the two attribute velocities, equivalent to increasing the 'buffer' to better fit the acceleration condition. We also built a model for the men's competition at the Tokyo Olympics, and after increasing multiple intermediate speeds, the performance was improved.

(2) To formulate strategies from the macro perspective, it is inevitable to make certain mistakes in the micro perspective. However, our model is relatively stable, and these flaws have very little and

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negligible impact on the model.

References

[1] Leo, P., Spragg, J., Podlogar, T. et al. Power profiling and the power-duration relationship in cycling: a narrative review. Eur J Appl Physiol 122, 301–316 (2022).
[2] Fabio Malizia, Bert Blocken, Bicycle aerodynamics: History, state-of-the-art and future perspectives, Journal of Wind Engineering and Industrial Aerodynamics, Volume 200, 2020, 104134, ISSN 0167-6105,
[3] de Jong J, Fokkink R, Olsder GJ, Schwab A. The individual time trial as an optimal control problem. Proceedings of the Institution of Mechanical Engineers, Part P: Journal of Sports Engineering and Technology. 2017;231(3):200-206. doi:10.1177/1754337117705057
[4] https://www.la-flamme-rouge.eu/maps/viewtrack/382547
[5] https://www.procyclingstats.com/race/world-championshipitt/2021/result/today/profiles
[6] https://www.procyclingstats.com/race/world-championship-itt/2021
[7] https://www.la-flamme-rouge.eu/maps/viewtrack/245739
[8] https://www.la-flamme-rouge.eu/maps/ viewtrack/245738
[9] https://youtu.be/4u5Iv-C225U
[10] https://www.uci.org/
[11] https://cyklopedia.cc/cycling-tips/power-profile/
[12] https://www.cyclingweekly.com/news/racing/olympics/olympic-cycling-raceroute-357988