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Research and Application of Power Distribution Model Based on Simulated Annealing Method

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Abstract: This paper focuses on the power distribution curve and establishes a power distribution model based on the influence of external resistance and the nature of the object. The power supply model was established by the influence of external physical factors on the object using a physical analysis method. Combining the two models, the driver was identified, the initial edge conditions were determined, and a system of differential control equations containing three parameters was established. For the time problem with trajectory, a single-objective optimization model with the minimum time as the objective was established. Firstly, the maximum power provided by the drive is determined; secondly, the constrained objective function is determined as the process limit; secondly, the constraints are simulated and annealed and the power is searched using a circular traversal method.

1. Introduction

The simulated annealing algorithm is an optimization algorithm that can effectively avoid falling into a serial structure of local minima and eventually converge to a global optimum by giving the search process a time-varying and eventually zero probabilistic jump. The algorithm starts from a certain high initial temperature, and along with the decreasing temperature parameter, it combines certain probabilistic jump characteristics to randomly search for the global optimal solution of the objective function in the solution space, i.e., the local optimal solution can probabilistically jump out and eventually converge to the global optimal.

We need to develop a model that can be applied to any type to determine the relationship between the position of the object on the track and the power. We extract track information, design the track ourselves, and build a model that better fits physical reality to discuss specific factors.

2. Power Supply Model

2.1 Driver power curve model

In this part, we do not consider the influence of the characteristics of the track (assuming that the terrain of the track is balanced to adapt to the ability characteristics of different types of players), and we use the Power Proflie indicator to reflect this. Power Proflie:It tells us more about competitors' abilities in cycling. Here are four important values which tell us about:sprint abilities, anaerobic capacity ,VO2 max capability and FTP (Functional Threshold Power). Values and Measurement Indicators is shown as table 1.

Table 1: Values and Measurement Indicators

values	Sprint abilities	Anaerobic capacity	VO2 max capability	FTP
Maximum power described by	5s	1min	5min	20min

According to the data of the players participating in the competition which Coach Damian has provided in his article. We can see the four indicators of different types of players, assign values according to the data relationship, and get the following histogram. We can see the four indicators of different types of players, assign values according to the data relationship, and get the following histogram.[1]The strengths and weaknesses of the four abilities of different types of players is shown as figure 1.

In addition, considering that the ability of athletes of the same type and different genders on the same index is also different, according to the research on the physiological structure of different genders, the muscle mass of men and the metabolic level under aerobic and anaerobic conditions are 8% ~ 12% higher than that of women on average. In order to simplify the model, we make each index of men 10% higher than that of women. The data index of men is the average level of riders, which is sorted into the figure below. Gender difference in the four abilities is shown as figure 2.

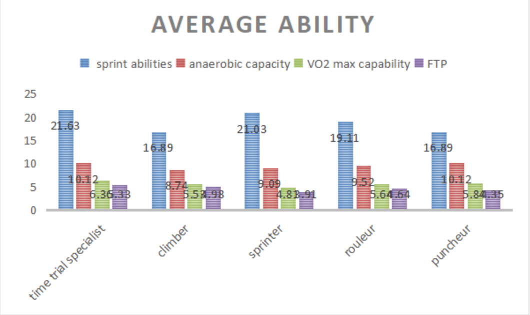

Figure 1: The strengths and weaknesses of the four abilities of different types of players

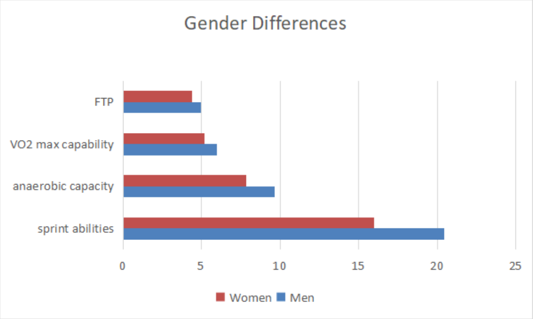

Figure 2: Gender difference in the four abilities

In terms of the player's output power, we first define the concept of two critical values:

P_{max}: The maximum power that the player can output in the initial state.

(Critical Power): Players eventually tend to reach the power value at the limit of physical fitness, and the power curve eventually stabilizes around this value. If the power output is forcibly increased, the speed of physical exhaustion will be greatly accelerated.

Among them, P_{max} is mainly affected by anaerobic capacity and sprint abilities, because both can measure the initial power at the best state or the maximum power at the strongest burst. [2]

Among them, CP is mainly affected by FTP and VO2 max capability, because the two are mainly to measure the state of the player in the fatigue period or the long-term physical output.

To simplify the model, we let the average level of anaerobic capacity and sprint abilities determine the value of P_{max} ,and set the average level of P_{max} as 1200W. Let the average level of FTP and VO2 max capability determine the CP value, and set the average level of CP as 300. The P_{max} and CP values obtained from different players' ability indicators are sorted and tabulated, and the following sum s of players of different types and genders can be obtained data distribution , as shown in Figure 3.

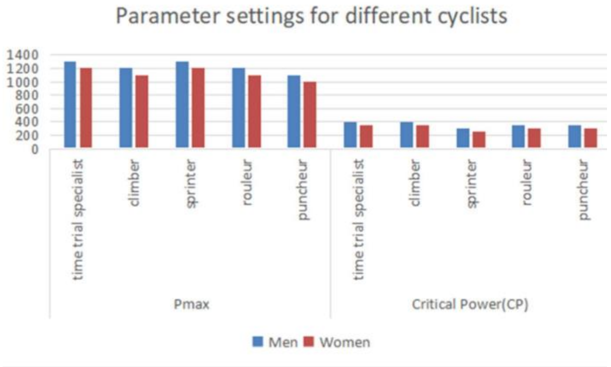

Figure 3: Parameter settings for different cyclists

An omni-domain power-duration model (OmPD):

By processing the power data in the schedule of multiple players and taking the OmPD model as a reference, we can roughly fit the power function P(t).

$$P_{(t)} = CP + m * (1 - e^{kt}) \tag{1}$$

$$\mathrm{m} = \frac{W'}{t} \tag{2}$$

where W' represents the work done by the player in the time from start to t.

$$W' = \int (P(t) - CP)dt \tag{3}$$

Since the human body produces lactic acid at any time, when the riding intensity exceeds a certain value, the lactic acid production will continue to increase, resulting in the unmaintainable dynamic balance of the body, and the accumulation of a large amount of lactic acid will affect muscle contraction and cause muscle fatigue.

Therefore, it is necessary to consider the factors that the players will gradually get tired, and then according to the image drawn from the extracted data, it can be analyzed that as the competition progresses, the output power of the players decreases exponentially, and the coefficient k of this exponential function part is: [3]

$$\mathrm{k} = -\left(\frac{P_{max} - CP}{W'}\right) \tag{4}$$

Therefore, the player power curve model can be obtained:

$$\mathrm{P(t)} = \mathrm{CP} + \frac{(P(t)-CP)dt}{t} * (1 - e^{-t*(\frac{P_{max}-CP}{\int(P(t)-CP)dt})}) \tag{5}$$

According to the difference method, Peter Leo (2021) studies data on the power of different players. The player power curve model established by us uses the least squares method to exponentially fit the data, and establishes the player's average power output power curve.

2.2 Model verification:

The picture is the visualization curve of the player's power output model established by J. Point (2020) in his research paper. The picture is that we take the climber type player as an example and substitute its P_s and CP parameters into the player power we established Curve model. The power visualization curve is established based on the game time and the ordinate of the player's power output at that moment. Let the average weight of J. Point research subjects be 60kg. After comparison, it is found that there is a certain degree of coincidence with the curve values and images obtained by the model we established, which can prove that our model is in line with reality. Quotation of J. Point's image and our power curve is shown as figure 4. [4]

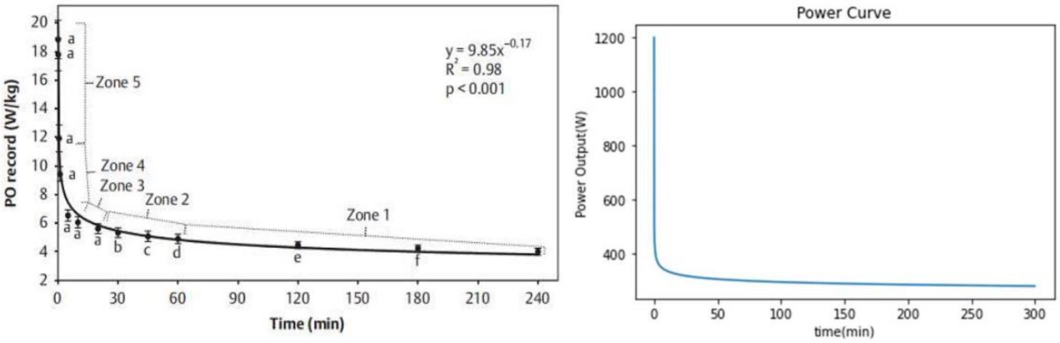

Figure 4: Quotation of J. Point's image and our power curve

3. Track model

In this part, the differences in the types of players are not considered for the time being, and only the power that players need to provide when passing the track during the race is analyzed. The following images show 2021 UCI World Championship time trial course in Flanders, Belgium and 2021 Olympic Time Trial course in Tokyo, Japan. We extract the specific information of the track shape based on the track data provided by the official and make a drawing representation. Track information is shown as figure 5. Course profile is shown as figure 6. [5]

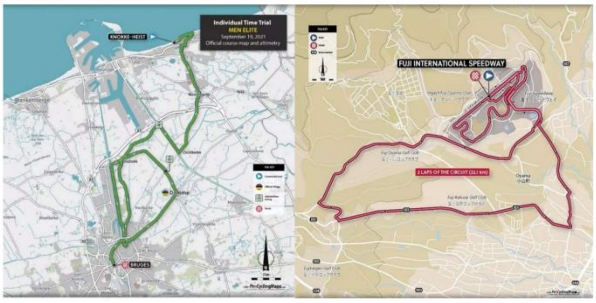

Figure 5: Track information

Track extraction process: we use python, according to the binary algorithm, set the corresponding threshold, extract the track edge contour, enlarge the graph according to the corresponding scale, take a point every 50 meters on the map, take the track starting point as the origin, get the coordinate point data of the point on the track, fit the data in turn with Python, and draw the track image as figure 7. [6]

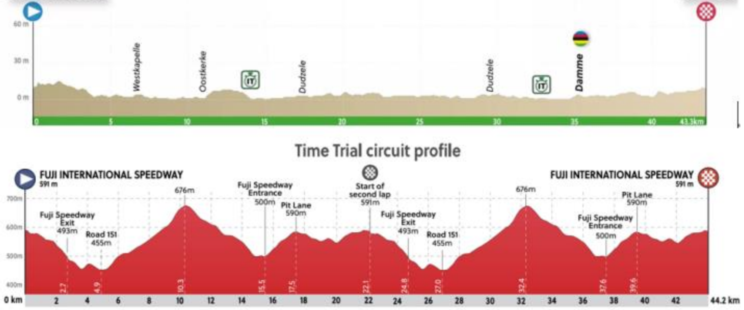

Figure 6: Course profile

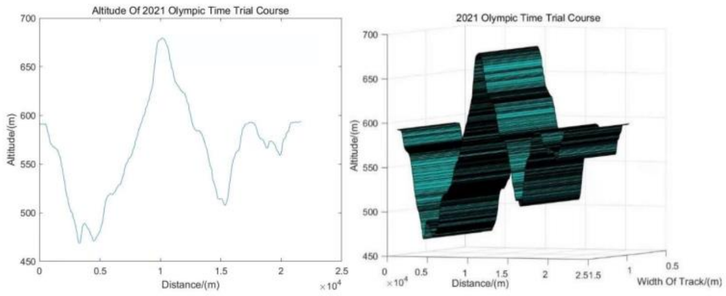

Figure 7: Image of the race track

During the competition, players will pass through areas such as the uphill track, corners, and straight sections. They need to overcome the influence of their own weight and work to increase potential energy and maintain kinetic energy; [7] The work done by the frictional resistance and the influence of the wind speed on the driver's power can be known from aerodynamics to form wind resistance, which all have a certain power consumption. [8]Power consumption of cyclists is shown as figure 8.

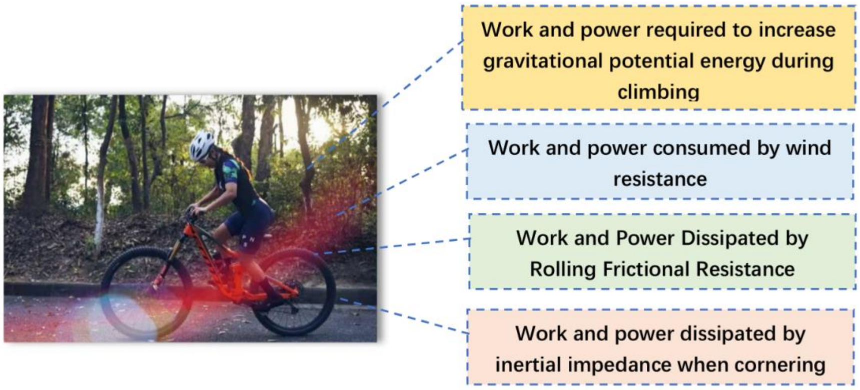

Figure 8: Power consumption of cyclists

Set the work and power required to increase the gravitational potential energy when climbing the slope as W_1 and P_1 respectively, set the slope angle as θ, the displacement during the integration time as x, and the derived $\dot{x}$ is the corresponding speed.

$$W_1 = \int mgsin\theta dt \tag{6}$$

$$\mathrm{P} = \frac{W}{t} \tag{7}$$

$$P_1 = mgsin\theta x \tag{8}$$

Assuming that the work and power consumed by overcoming the rolling frictional resistance are W_2 and P_2 respectively, then:

$$W_2 = \int mg\mu cos\theta dx = \int mg\mu cos\theta x dt \tag{9}$$

$$P_2 = W_2' = mg\mu cos\theta x \tag{10}$$

Let the work and power consumed by overcoming the inertial impedance when turning are W_3 and P_3 respectively, Let the radius of curvature of the curve be R. At this time, the human-vehicle system has both translational kinetic energy and rotational kinetic energy because it has speed and is turning. To make the system have these two functions, the system needs to do work:

$$W_3 = \frac{1}{2}mx^2 + \frac{1}{2}J_1(\frac{x}{R})^2 + \frac{1}{2}J_2(\frac{x}{R})^2 \tag{11}$$

Among them, J_1 and J_2 represent the moment of inertia of the front and rear wheels of the bicycle, respectively.

$$P_3 = mxx + \frac{J_1}{R^2}xx + \frac{J_2}{R^2}xx \tag{12}$$

Since we will specifically discuss the influence of the external environment, including wind resistance, on the players in the following model, here we temporarily set the work and power to overcome wind resistance as W_4 and P_4 without further discussion. [9] In summary, the power consumption model of the human-car system on the track is:

$$\mathrm{P} = P_1 + P_2 + P_3 + P_4 = mg(\mu cos\theta + sin\theta)x + \left(\mathrm{m} + \frac{J_1}{R^2} + \frac{J_2}{R^2}\right)xx + P_4 \tag{13}$$

Another practical consideration is that the track has undulations, which can affect time and power on the uphill and downhill sections. Compared with the ideal straight section, in order to achieve the optimal distribution of physical strength, the runners should provide more power on the uphill section; relatively reduce the output power on the downhill section. At the same time, it is necessary to ensure that the use time is as short as possible, and also to prevent excessive fatigue after the outbreak. The following three-dimensional images show the increase or decrease in the total time to complete the race caused by different track conditions (uphill and downhill), the three dimensions are Total time(s), Power reduction in downhill slope (W) and Power addition in uphill slope.Power of downhill and uphill & total time is shown as figure 9 and figure 10.

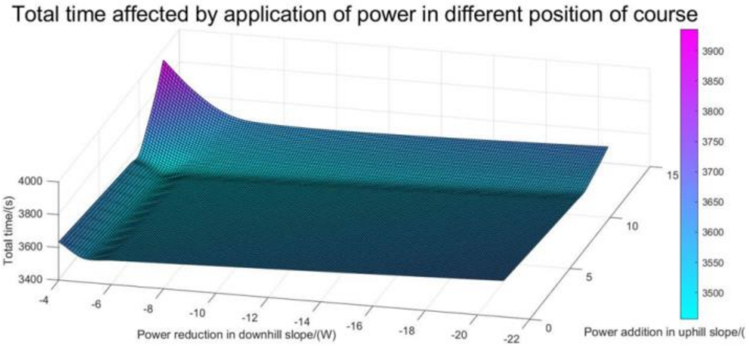

Figure 9: Power of downhill and uphill & total time

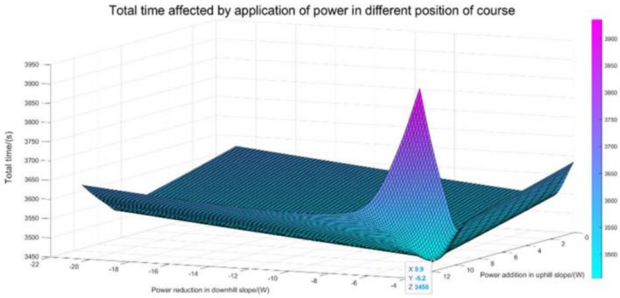

Figure 10: Power of downhill and uphill & total time

Our target decision is time t, which is affected by two independent variables, Power reduction in downhill slope and Power addition in uphill slope. According to the power distribution model established above, we can get the change of race time t with the two independent variables, as shown in the figure above. Show. The coordinates of the lowest point of the image can be obtained as (9.9, -5.2, 3456), that is, the shortest time is 3456 seconds [10].

4. Conclusion

The development of road bicycles has a long history, cyclists always hope to complete the race in the shortest time on a fixed track, and the power distribution of the rider will affect the time to finish the race. This paper mainly studies the driver's power distribution curve, establishes a power distribution model based on the influence of external resistance and the nature of the driver, and uses the least squares method, the difference method, and the simulated annealing algorithm to solve the problem. For the driver's power distribution problem, the driver's ability matching model is established for the five types of drivers in the question according to their own nature and driver's own factors. Through the influence of external physical factors on the rider, the analysis method of physics is applied to establish the power supply model of the rider. Combining the two models, the driver is determined, the initial boundary value condition is determined, and a differential control equation system containing three parameters to be determined is established.

The difference method is used to solve the equation system layer by layer, and based on the principle of least squares, the actual power curve of the driver is obtained, and the optimal parameter combination is obtained by traversal. After substituting this group of parameters, the global power-time matching model is obtained. For the time problem with a track, a single-objective optimization model is established with the shortest time as the goal. First, determine the maximum power provided by the driver; secondly, determine the constraint objective function as the process limit; secondly, perform simulated annealing on the constraints; then, apply the power distribution model in requirement 1, and use the cyclic traversal method to search for the power The driver's shortest time at the Tokyo circuit and the Belgian circuit under the assigned conditions were 3304 seconds and 22648 seconds.

References

[1] Nakano Kotaro, Chakraborty Basabi. Real-Time Distraction Detection from Driving Data Based Personal Driving Model Using Deep Learning[J]. International Journal of Intelligent Transportation Systems Research, 2022(prepublish).
[2] Dong X, Wu Z, Song G, et al. A hybrid optimization algorithm for distribution network coordinated operation with SNOP based on simulated annealing and conic programming[C]// Power & Energy Society General Meeting. IEEE, 2016.
[3] Jamonnak Suphanut, Zhao Ye, Huang Xinyi, Amiruzzaman Md. Geo-Context Aware Study of Vision-Based Autonomous Driving Models and Spatial Video Data. [J]. IEEE transactions on visualization and computer graphics, 2021, PP.

[4] Jiangling Hong, Hongjie Zhang, Jiaqi Wang, Jinbo Liu, Honglei Liu, Chaodong Tan, Pengkun Hou, Wenrong Song. Data Driven Model of Gas Well Integrity and Its Application[C]//. Proceedings of 2021 5th International Conference on Electrical, Automation and Mechanical Engineering (EAME2021). , 2021:674-681. DOI:10. 26914/c. cnkihy. 2021. 044445.

[5] Wang Yuqi, Li Yunzhu, Zhang Di, Xie Yonghui. Aerodynamic optimization of a SCO₂ radial-inflow turbine based on an improved simulated annealing algorithm[J]. Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy, 2021, 235(5).

[6] Almuhaideb Sarab, Altwaijry Najwa, AlMansour Shahad, AlMklafi Ashwaq, AlMojel Khalid AlBandery, AlQahtani Bushra, AlHarran Moshail. Clique Finder: A Self-Adaptive Simulated Annealing Algorithm for the Maximum Clique Problem [J]. International Journal of Applied Metaheuristic Computing (IJAMC), 2022, 13(2).

[7] Tanha Mozhdeh, Hosseini Shirvani Mirsaeid, Rahmani Amir Masoud. A hybrid meta-heuristic task scheduling algorithm based on genetic and thermodynamic simulated annealing algorithms in cloud computing environments[J]. Neural Computing and Applications, 2021, 33(24).

[8] Zhang Lifeng, Zhang Menghan. Image reconstruction of electrical capacitance tomography based on optimal simulated annealing algorithm using orthogonal test method [J]. Flow Measurement and Instrumentation, 2021, 80.

[9] P. Prakasam, T. R. Suresh Kumar, T. Velmurugan, S. Nandakumar. Efficient power distribution model for IoT nodes driven by energy harvested from low power ambient RF signal [J]. Microelectronics Journal, 2020, 95(C).

[10] R. Maurizio, B. P. Duval, B. Labit, H. Reimerdes, C. Theiler, C. K. Tsui, J. Boedo, H. De Oliveira, O. Février, U. Sheikh, M. Spolaore, K. Verhaegh, N. Vianello, M. Wensing. Conduction-based model of the Scrape-Off Layer power sharing between inner and outer divertor in diverted low-density tokamak plasmas [J]. Nuclear Materials and Energy, 2019, 19.