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The Design of Half-pipe Snowboard Based on Genetic Algorithm

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Abstract. In this paper, we studied the design about the snowboarding runs based on Genetic Algorithm (GA). GA is an adaptive optimized algorithm of probability search which simulates heredity and evolution of biology in environment. Assuming athletes reach the highest height as they can, we proposed a model with flight height as objective function. And then we figured out the ski runs' length, radius of curvature, angle of inclination and width of bottom platform by using GA.

1. Introduction

The skiers, who join half-pipe snowboarding, always need to finish some highly difficult movement in the air such as fly, catch the board and twist [1]. The ski run is a snowy trail in U shape, which is usually consist of bottom, transition and perpendicularity in international scene [2].Skier reaches to the edge of half pipe with a certain initial velocity, then ski in it back and forth. Every time leaving the edge, they do five to eight movement in the air like twist or jump. Finally, skier are given marks for degree of difficulty and their performance. However, the proper designing of half pipe, like its slope and arc length, the radius of the semicircular runs, is important for skiers performance. So it has a great theoretical significance to use an effective algorithm to figure out the optimal value of skiers' flight height.

2. Introduction of GA

The implementation of GA include coding, generating groups, calculating fitness, duplicating, exchanging, varying and so on [3]. Based on the principles of natural evolution, GA simulate the natural laws that natural selection assures the survival of the fittest when calculate optimal value. We set independent variable to organism, and transform it into chromosome making up with gene. Then set optimization objective function to fitness, set unknown functions to living environment, finally resolved the optimal value by genetic manipulation like duplicating, varying, etc.

3. Establishment of Model

3.1 Assumptions of Model

1. Assuming the angle between the orientation of skiers' velocity and runs plane remains the same.
2. Ignoring the influence of air resistance when skiers ski.
3. Assuming it is quadrant between vertical edge and horizontal edge in the half pipe, the skiing routes in the flat part is straight. Ignoring the influence of friction in vertical edge.

3.2 Construction of Objective Function

According to the assumptions, skiers' height of leaving run and entering run will be the same. As is shown in Fig.1, we set leaving-run height to H.

$$H = BC \cdot \tan\beta \quad (1)$$

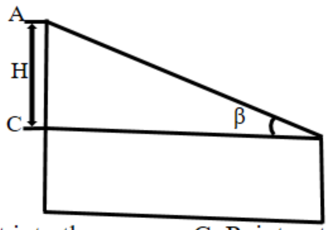

Figure 1. Profile of half pipe

Then, based on the geometrical relationship in Fig.2.

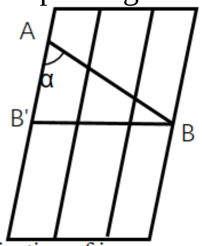

Figure 2. Unfolded drawing of half pipe

$$BC = AB' = \frac{BB'}{\tan\alpha} \tag{2}$$

$$BB' = D + 2R \tag{3}$$

$$H = \frac{D+2R}{\tan\alpha}\tan\beta \tag{4}$$

H is skiers' theoretical flight height, D is the width of straight run, R is radius of circular run, α is the angle between the orientation of skiers' velocity and the down orientation along the run, β is the slope of half pipe.

Because of W_f, which is the friction loss while skiing, skiers' flight height decreases to $\frac{W_f}{mg}$. As a result, the actual height h is

$$h = H - \frac{W_f}{mg} \tag{5}$$

W_C is the work corresponding to friction loss in two arc runs, W_L is the work corresponding to friction loss in tilted and straight runs.

$$W_f = W_C + W_L \tag{6}$$

According to Newtonian mechanics, relation between work and energy and mathematical operations, we have:

$$W_C = \mu mgR\sin\alpha + \frac{2\cos\alpha}{\pi\tan\alpha}\mu m + m\frac{\bar{v}^2}{R}\sqrt{\left(\frac{\pi}{2}R\right)^2 + \left(\frac{R}{\tan\alpha}\right)^2} \tag{7}$$

$$W_L = \mu mg\frac{D}{\sin\alpha} \tag{8}$$

$\bar{v}$ is skiers' average speed on the run.

To sum up, we can figure out the objective function of h is

$$h = \frac{(D+2R)\tan\beta}{\tan\alpha} - \left(\frac{4\mu\cos\alpha}{\pi\tan\alpha}R + 2\mu R\sin\alpha + \frac{\mu D}{\sin\alpha}\right) - 2\frac{\mu\bar{v}^2}{gR}\sqrt{(\frac{\pi}{2}R)^2 + (\frac{R}{\tan\alpha})^2} \tag{9}$$

According to spatial geometry, we can figure out l_0, which is the distance skiers advance in one time.

$$l_0 = \frac{D+2R}{\tan\alpha} + \frac{2v_c^{\,2}\sin\alpha\cos\alpha}{g} \quad (10)$$

The total length of skiing runs.

$$l = 5l_0 = 5\left(\frac{D+2R}{\tan\alpha} + \frac{2v_c^{\,2}\sin\alpha\cos\alpha}{g}\right) \quad (11)$$

3.3 Parameters Analysis with Genetic Algorithm

The expression of maximum height h is a multivariate function. Considering the factors like complex functions and so on, we cannot calculate the maximum by ordinary ways like Lagrange multipliers. Therefore, we use GA to calculate the maximum of h. Then put the five parts, radius of curvature r, the width of bottom platform d, angle of inclination θ, the angle between skiers-leaving-run and edge of run β, average velocity, as five genes at one chromosome.

Firstly, we encode every gene. We can regard every independent variable as phenotype in GA because they are real number, and use binary code in the mapping which we map phenotype to genotype.

If assuming the minimum precision is not lower than 0.001, we can use 10 digit for every variable to meet the requirement. Because objective function is a function of five variables, every chromosome need to have 5 genes. The length of every gene is 10, so the total length of every chromosome is 50. Thus, a 100×5 matrix is generated. Therefore, the initial group is generated. An individual genes are generated randomly by a binary string which length is 40. Then we can generate a group constituted by several individual, the size of which is the number of individual.

Secondly, we determine the fitness in this genetic manipulation. In this paper, objective function his fitness. The higher skiers-reaching height is, the bigger objective function is, the higher fitness is.

Thirdly, we select optimal individual. During this process, we use roulette wheel selection [4] which is simpler than others. In order to select individuals for mating, we need to select for several rounds. Every round generate one uniform random number from [0, 1] which is used to select the individual as a pointer. Finally, we conduct genetic manipulation. With analysis, we find that one gene difference can make it a great disparity to corresponding parameter values for individuals encoded by binary. If we use Gray code [5] in crossover and mutation part, one digit difference in a binary string will make little difference to the corresponding parameter values. In these way, capability of local research can be enhanced, and it will be convenient for continuous function to search in local space. So, in this step, we choose Gray code instead of binary code to conduct genetic manipulation.

4. MATLAB Simulation

We take related data about half-pipe snowboard, which is shown in the following part, as reference to ensure the scope of local space.

Table 1. Reference Data of Half-pipe Snowboard

Related data	**minimum**	**Suggested value**	**maximum**
Slope θ	14 °	16 °	18 °
Length l	100 m	120 m	140 m
Width of bottom d	8 m	8.5 m	9 m
Depth of half pipe r	3 m	3.5 m	4.5 m
Angle of leaving-run	40 °- 70 °		

We take some elite athletes' kinematic parameter as reference to ensure skier' instant velocity when leaving the run.

Based on the idea mentioned about, we solved H in MATLAB condition, the maximum of which is 4.7 m. When H is taken the max value, the value of every parameters is in Fig.3.

Table 2. Some Elite Athletes' Kinematic Parameter

Athlete	**Wancheng Shi**	**Zhifeng Sun**	**Shiying Huang**	**Xiaoye Zeng**	**Jiayu Liu**	**Lei Pan**
instant velocity of board's front edge-leaving-run (m/s)	11.39	10.20	13.73	11.65	11.20	12.00
instant velocity of entire-board-leaving-run(m/s)	7.73	8.24	12.09	11.55	9.82	9.11
instant velocity of skier-leaving-run (m/s)	9.56	9.22	12.91	11.60	10.51	10.56
Average value (m/s)	10.73					

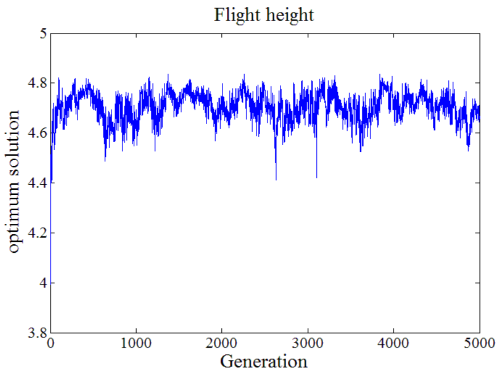

Figure 3. Simulation result of optimal value

Obviously, there are variations in it. So with the addition of horizontal axis' value, local optimal value cannot appear on vertical axis.

Table 3. Results of Half-pipe related value

parameter	**Slope θ**	**Width of bottom d**	**Depth of half pipe r**	**Angle of leaving run α**	**Length L**
value	19°	8.7 m	4.3 m	50°	130 m

It's just a suggestion to skiers that the value of α is 50°. According to the design of run, if skiers can make the angle between skiers-leaving-run and the edge of run approaching to 50°, their reaching height can be as high as possible.

5. Conclusion

In this paper, we studied the design about half-pipe snowboard particularly and proposed a retrofit scheme based on GA. In MATLAB condition, parameters can be calculated in a short time. It turned out that using GA can improve accuracy a lot in parameter calculating about design of half-pipe snowboard, comparing to international standard. At the same time, the flight height we calculated can guarantee skiers making best effect of performance.

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