Quest Journals
Journal of Research in Applied Mathematics
Volume 6 ~ Issue 3 (2020) pp: 12-19
ISSN(Online) : 2394-0743 ISSN (Print): 2394-0735
www.questjournals.org

Research Paper

New Roller Coaster Rating System and Its Application

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ABSTRACT: *With the development of society, people are increasingly pursuingspiritual enjoyment. Ferris wheel and roller coaster have become popular forms of entertainment. It is especially significant to establish an appropriate evaluation standard for roller coasters. Fortunately, the nonlinear comprehensive evaluation model provides us with new ideas to solve this problem.First, we have established a set of indicators to analyze the decisive factors for people choose roller coasters. According to the analysis results, we selected nine indexes: height, speed, full length, times of turns, maximum drop height, running time, gravity, height angle and material. After the data are normalized, entropy method is used to obtain the weight of the nine indexes, and then the weight is given to the nonlinear weighted comprehensive model to get the rating system of roller coaster.Second, we use our model to get the top 10 of the roller coasters. Comparing our ranking with the roller coaster excitement ranking on the website. We find a big difference between the two rankings. While considering some objective criteria, roller coaster ranking websites rely seriously on subjective input to determine roller coaster ranking.Next, according to the nine indexes previously selected and ticket prices. We made a test ride system to recommend roller coasters for tourists. We are developing our " private custom" APP at this stage. It is used to select the roller coaster for among roller coaster rider.Finally, we compile our technical achievements into a press release.*

Received 08November, 2020; Accepted 23 November, 2020 © The author(s) 2020.
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I. INTRODUCTION

1.1 Background

The equipment of roller coaster is mainly composed of train, pillar, track, lifting and braking system. Its structure and movement form are complex. At the beginning of the operation, it relies on mechanical devices to transport the small train to the highest point, and then realizes the roller coaster operation under the action of gravity[1]. Roller coasters are big rides that people love especially teenagers. The roller coaster ranking sites rely heavily on subjective input to determine roller coaster rankings, while considering some objective measures. Our team will establish an objective quantitative algorithm to rank the roller coaster.

1.2 Restatement of problems

In this paper, we break our work into sections as follows.
Task 1. Developing a descriptive roller coaster rating system by studying the numerical and descriptive specification data of roller coaster.
Task 2. Making a reasonable description by comparing our team's rating and ranking system with others on the Internet.

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Task 3. Using our algorithm to help the roller coaster rider find the roller coaster which he wants to ride.
Task 4. We need to write a non-technical press release which includes the algorithms, results, and application program.

1.3 Overview of work

- On the basis of the original data, the missing values were supplemented by the sequential average method and the multiple interpolation method.Then the qualitative index is quantified and the data is processed uniformly. We calculate the weight by entropy method, and then give the weight value to the nonlinear weighted comprehensive model. In the end, we get the roller coaster rating system.
- Comparing the top 10 roller coasters by our rating system to the online roller coaster ranking.
- Original indicators and roller coaster ticket prices were used as the screening gist. Then, we can select the

appropriate roller coaster for among roller coaster rider.

- We compile our technical achievements into a press release.

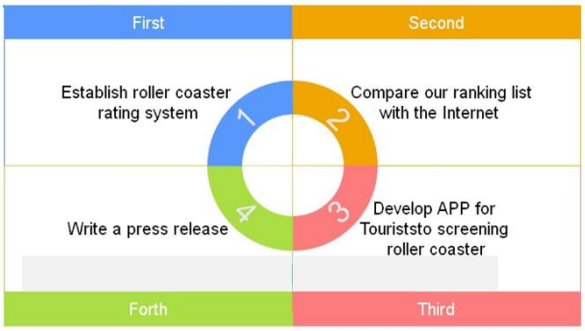

Figure 1: General flow chart

II. ASSUMPTIONS AND JUSTIFICATION

- **Assumptions Ⅰ:** The results of the 896 satisfaction surveys are reliable.

Reason: We can use the sample to estimate the overall effect.

- **Assumptions Ⅱ:** The data filled by the multiple interpolation method are within a reasonable range.

Reason: It can make the later operations have a reasonable basis.

- **Assumptions Ⅲ:** In the entropy method, we substitute 0.000001 for the zero in the evaluation matrix.

Reason: The evaluation matrix containing 0 cannot be calculated by entropy method.

III. SYMBOLS AND DEFINITIONS

In the section, we use some symbols for constructing the model as follows:

Table 1: Symbols and Definitions

Symbols	Meanings
Roller coaster evaluation system	R
Height	H
Speed	S
Length	L
Times of Inversions	T
Drop	D
Duration	U
Force	F
Vertical Angle	V
Construction	C

IV. DATA PREPROCESSING

Thedata file "COMAP_RollerCoasterData_2019" provides us with the roller coaster's basic data all of the world. This is a huge amount of data with lots of abnormal and missing data. Therefore, we need to perform data preprocessing by cleaning, selecting and normalizing the data.

4.1 Addressing the Missing Values

1. As the last four indicators of some types of roller coasters are null. They belong to abnormal data and should be deleted.
2. For columns with fewer missing values, we use the sequence average method to supplement the missing values.
3. Four columns of data, drop, duration, force and vertical angle, contain a large number of missing values. We used multiple interpolation to deal with missing values.

- Selecting four variables which need to supplement with missing values.
- Selecting analysis weight.
- Selecting interpolation times.
- Establishing constraints for four variables.

4.2 Quantitative treatment of qualitative indicators

Roller coaster tracks can be made of steel and wood. We quantified this indicator. We distributed the satisfaction survey scoring form (10 - point system) to 1,000 visitors. We received 896 valid satisfaction scoring forms. The

roller coaster satisfaction rating tables of the two materials are averaged to obtain 7.9 points for wooden roller coasters and 5.6 points for steel roller coasters.

4.3 Date Normalization

Since we will use indicators with various units, we have to normalize all the indicators and scale all the values in the range [0,1]. Formula (1) gives the general form of the adopted normalization. Range method:

$$X_{new} = \frac{x - x_{\min}}{x_{\max} - x_{\min}} \qquad (1)$$

Where $x_{\max}$ and $x_{\min}$ are respectively the maximum and minimum value of the indicators in the same unit.

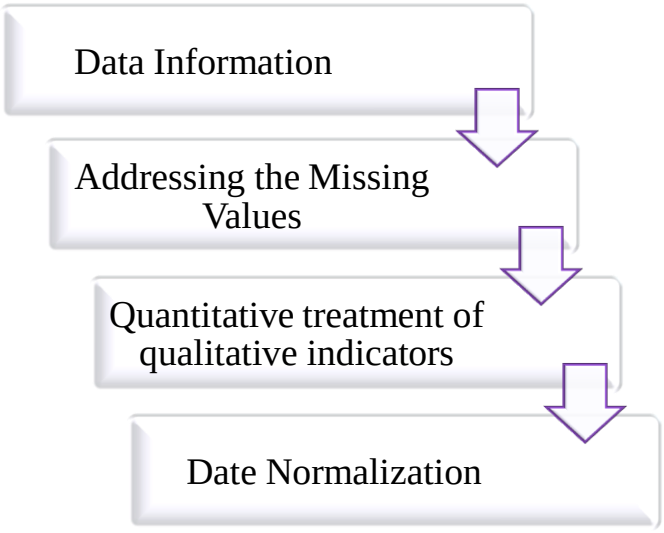

Figure 2: The flow chart of data preprocessing

V. MODEL DESIGN

5.1 Roller coaster rating system

5.1.1 Modeling Ideas

For the roller coaster rating system, we selected 9 indicators to evaluate the roller coaster. In this section, we use entropy method is to calculate the weight coefficients of 9 indexes. Then, weight values are given to the nine indexes. In the end, a roller coaster ranking system is obtained by using nonlinear weighted synthesis model.

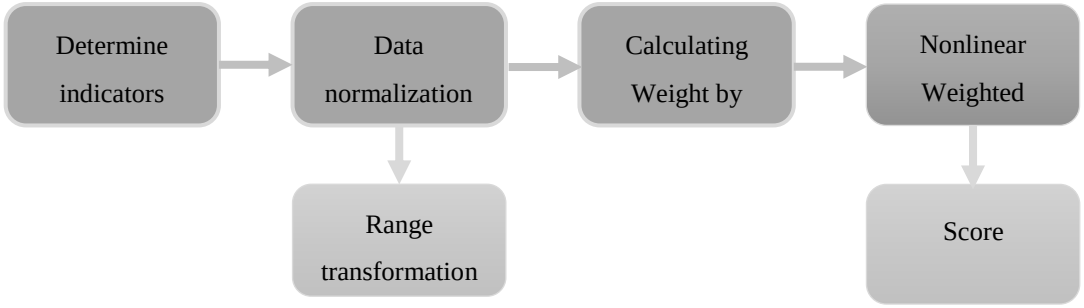

Figure 3: The flow chart of model processing

5.1.2 Supplementary Assumptions and Justification

For the qualitative indicator of material quality, we assume that the results of 896 satisfaction surveys are true and reliable. we can use this sample to estimate the overall effect. In this way, we can quantify the qualitative index of material.

5.1.3 Articulate Evaluation Forms

The evaluation criteria for roller coasters mainly include the following nine aspects: height, speed, full length, times of turns, maximum drop height, running time, gravity, height angle and material. The section will focus on these nine aspects [2].

- **Speed:** The speed of roller coaster is an important factor when people play roller coaster. Faster speed can give people better mental experience.
- **Height:** Higher height will bring quicker speed and have more pattern experience before landing.
- **Full length:** Long roller coaster track gives people a long game experience.
- **Turnover Times:** Many tourists like to overturn many times. When the roller coaster turn over, they can indulge in this sudden excitement.
- **Maximum drop height:** The maximum drop height of the roller coaster brings more exciting limit drop to tourists.
- **Running time:** The longer running time means that tourists can enjoy the scenery along the way. Equally, they can enjoy the excitement.
- **Gravity:** Gravity can provide centripetal force. Thus, it can improve safety index. Weightlessness will affect the rider's body to some extent.
- **Height Angle:** The height angle of roller coaster is very intuitive for tourists' experience. When the height angle is large, tourists can easily see the panorama and have more exciting spiritual feelings.
- **Material:** Roller coaster tracks are made of wood and steel. We provided questionnaires to some tourists. Most tourists reflect that the wooden can make a sound when tourists play them. The sound makes people feel more exciting.

5.1.4 Entropy method for weight

In the data given in this article, thedata file"COMAP_RollerCoasterData_2019" has a large amount of information. We use entropy method to find the weight coefficient of these nine indexes. When the amount of information is large, the entropy value is small and the utility value of the message is large [3] [4].

The process of calculating weight by entropy method is following:

- Calculating the characteristic proportion of the I -TH evaluation object under the j - TH index.
- If the observed values of m indicators of n evaluation objects are $x_{ij}(i=1,2,\cdots,n;\ j=1,2,\cdots,m)$ ($x_{ij} \geq 0$ and $\sum_{i=1}^{n} x_{ij} > 0$).

Then, the characteristic proportion of the i evaluation object under j item indicator is

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}}, (i=1,2,\cdots,n;\ j=1,2,\cdots,m)$$

- The entropy value of j item is calculated as follows:

$$e_j = -k\sum_{i=1}^{n} p_{ij}\ln(p_{ij}), (j=1,2,\cdots,m)$$

- The difference coefficient for calculating j item is $g_j = 1-e_j, (j=1,2,\cdots,m)$.
- Determine the weight coefficient of j item

$$w_j = \frac{g_j}{\sum_{k=1}^{m} g_k}, (j=1,2,\cdots,m)$$

Through the above calculation process, we can get that The weight value of roller coaster height, speed, full length, times of turns, maximum drop height, running time, gravity, height angle and material are 0.1776, 0.1188, 0.1283, 0.0061, 0.1714, 0.1281, 0.0753, 0.1842 and 0.0102.

5.1.5 The evaluation system of roller coaster

We tested the correlation of the above 9 indexes and got **Error! Reference source not found.**:

Table 2: The pertinence between indicators

	Height	Speed	Length	Number of Revolutions	Falling height	time	Gravity	Elevation angle	Material

Height Speed	1.000	.815**	.497**	-.025	.420**	.265**	.011	.161**	-.193**
	.	.000	.000	.692	.000	.000	.860	.009	.002
Length Numberof revolutions	.815**	1.000	.553**	-.175**	.410**	.222**	-.069	.139*	-.074
	.000	.	.000	.005	.000	.000	.267	.025	.234
Falling height time	.497**	.553**	1.000	-.208**	.041	.557**	-.278**	-.225**	.210**
	.000	.000	.	.001	.514	.000	.000	.000	.001
Gravity Elevation angle	-.025	-.175**	-.208**	1.000	-.027	-.084	.152*	.095	-.389**
	.692	.005	.001	.	.671	.177	.014	.128	.000
Material Height	.420**	.410**	.041	-.027	1.000	-.131*	.402**	.511**	-.302**
	.000	.000	.514	.671	.	.034	.000	.000	.000
Speed Length	.265**	.222**	.557**	-.084	-.131*	1.000	-.362**	-.356**	.058
	.000	.000	.000	.177	.034	.	.000	.000	.352
Number of revolutions falling height	.011	-.069	-.278**	.152*	.402**	-.362**	1.000	.530**	-.258**
	.860	.267	.000	.014	.000	.000	.	.000	.000
time Gravity	.161**	.139*	-.225**	.095	.511**	-.356**	.530**	1.000	-.254**
	.009	.025	.000	.128	.000	.000	.000	.	.000
Elevation angle	-.193**	-.074	.210**	-.389**	-.302**	.058	-.258**	-.254**	1.000
	.002	.234	.001	.000	.000	.352	.000	.000	.

By analyzing the above table, we find that there is a significant difference between the two indicators. Therefore, we say that there is a correlation between the nine indicators. In particular, the correlation is strong between speed and altitude, length, landing altitude and time.

We chose nonlinear weighted comprehensive model which is applicable to the strong correlation between various indexes to evaluate the roller coaster. Formula (2) is obtained to evaluate the stimulation degree of roller coaster.

$$R = H^{0.1776} + S^{0.1188} + L^{0.1283} + T^{0.0061} + D^{0.1714} + U^{0.1281} + F^{0.0753} + V^{0.1842} + C^{0.0102} \qquad (2)$$

Where	
Roller coaster evaluation system	R
Height	H
Speed	S
Length	L
Times of Inversions	T
Drop	D
Duration	U
Force	F
Vertical Angle	V
Construction	C

5.2 Roller coaster ranking system comparison

5.2.1 Our ranking system

Thedatafile "COMAP_RollerCoasterData_2019" is substituted into our ranking system and the roller coaster ranking is shown in **Error! Reference source not found.**:

Table 3: Our ranking system

Ranking	Name	Ranking	Name
First	*Steel Dragon 2000*	Sixth	Millennium Force
Second	Fury 325	Seventh	Schwur des Kärnan
Third	*Intimidator 305*	Eighth	Red Force
Forth	Leviathan	Ninth	Hyperion
Fifth	*Titan*	Tenth	*Steel Vengeance*

5.2.2 The excitement ranking of roller coaster online

We consulted the roller coaster ranking on the Internet and got the top 10 roller coaster excitements, as shown in **Error! Reference source not found.**:

Table 4: The excitement ranking of roller coaster online

Ranking	Name	Ranking	Name
First	*Intimidator 305*	Sixth	Tower of Terror
Second	*Steel Dragon 2000*	Seventh	Twisted Colossus
Third	*Titan*	Eighth	Wicked Cyclone
Forth	Kingda Ka	Ninth	Goliath
Fifth	*Steel Vengeance*	Tenth	Phantom's Revenge

Comparing our roller coaster rating system with the online roller coaster excitant ranking. We found that the first place we ranked was the third place on the Internet. Our third and fifth places are consistent with the second and third places online. Our tenth place is the fifth place on the internet. There are some similarities between the two ranking systems. It suggests that There are some common indicators selected by two marking system. There is a big difference between the two ranking systems. The roller coaster ranking websites online, rely seriously on subjective input to determine roller coaster ranking, while considering some objective criteria. It is relatively inappropriate. Therefore, we recommend to use our comprehensive evaluation model to rank the thrill of roller coasters.

5.3 Recommend the appropriate roller coaster for users

5.3.1 Design intent

In order to help the roller coaster rider find the roller coaster which he wants to ride, our team is developing a "private custom" APP. "Private Custom" APP is to select appropriate roller coasters according to roller coasters rider's needs. Then, we recommend roller coasters for them. Our APP, just like its name, is intended to select a roller coaster for every tourist to meet their needs.

5.3.2 Design principle

Our APP mainly consider the tourists' choice of the area where the roller coaster is located, as well as the funds, type, height, speed, acceptable time, maximum drop height, material and times of turns. We can select the suitable roller coaster for roller coaster riders through these factors. The process of screening roller coasters is shown in **Error! Reference source not found.**:

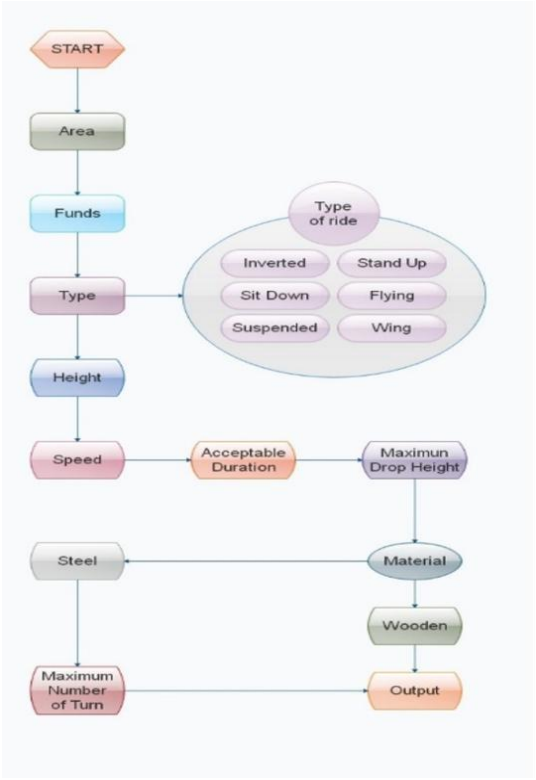

Figure 4: The flow chart of picking roller coaster

First of all, we need to determine where the tourists are located and what their price requirements are. Then, we can determine the type of ride that tourists like and their requirements for roller coaster height, speed, acceptable time and maximum drop height. Finally, the roller coaster track material is selected. The wooden rall of roller coasters no longer consider the times of turns (The web page data suggests that the wooden rall of roller coasters don't generally turn over because of safety needs). The roller coaster with steel rall can be recommended according to the maximum times of turns that the rider can bear. According to the above process, our APP can select the roller coaster that each roller coaster rider likes.

VI. NEWS RELEASE

Roller coaster ranking websites badly rely on subjective scorings to determine roller coaster ranking, while considering some objective criteria. Our team has made a new roller coaster rating system. We mainly considered nine factors of roller coaster: height, speed, full length, times of turns, maximum drop height, running time, gravity, height angle and material. We can get the formula of the new roller coaster rating system:(Table 1 is the symbol explanation of the formula)

According to our new ranking system, we can gain the top 10 exciting roller coasters:Steel Dragon 2000、Fury 325、Intimidator 305、Leviathan、Titan、Tower of Terror 、Twisted Colossus、Wicked Cyclone、Goliathand Phantom's Revenge.

Figure 5: Steel Dragon 2000

According to the factors we adopted when we establish the roller coaster evaluation model and the roller coaster ticket price,we are developing an APP which can provide selection service for users Our " private custom" APP forms a huge database by counting the basic information of the global roller coasters. Through the user's step-by-step selection, the " private custom" APP will select an appropriate roller coaster for among user.

VII. CONCLUSIONS

We set up a new roller coaster rating system. First, the missing data are processed and all indexes are disposed in a consistent way. Then we selected nine indicators: height, speed, full length, times of turns, maximum drop height, running time, gravity, height angle and material. The weight coefficients of nine indexes are gained by entropy method. Finally, we assign weight values to these nine indexes and use the nonlinear weighted comprehensive model to get the roller coaster ranking system.

Through our new ranking system, we can obtain the top 10 as follows:

Steel Dragon 2000、Fury 325、Intimidator 305、Leviathan、Titan、Tower of Terror 、Twisted Colossus、Wicked Cyclone、Goliathand Phantom's Revenge.

The top 10 exciting roller coasters on the website are as follows:

Intimidator 305、Steel Dragon 2000、Titan、Kingda Ka、Steel Vengeance、Tower of Terror 、Twisted Colossus、Wicked Cyclone、Goliath、Phantom's Revenge

After comparison, we find some similarities between them. It indicates that there are some identical indicators in the two ranking systems. But overall, they still have great differences. The roller coaster ranking websites rely badly on subjective scoring to determine roller coaster ranking, while considering some objective criteria. It is relatively inappropriate. Therefore, it is more recommend to rank the thrill of roller coasters with our new rating system.

According to the index we adopted when we set up the roller coaster evaluation model and the roller

coaster ticket price, we are developing an APP. It can provide selection services for tourists. Our " private custom" APP forms a huge database by counting the basic information of the global roller coasters. Through the user's step-by-step selection, the " private custom" APP will select an appropriate roller coaster for among user.

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Lili Wang. "New Roller Coaster Rating System and Its Application." *Quest Journals Journal of Research in Applied Mathematics* , vol. 06, no. 03, 2020, pp. 12-19.