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Model application research of javelin throwing problem based on computer simulations and gray prediction

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ABSTRACT

This paper studies the javelin inclined projectile motion. According to the inclined projectile motion principle, it is assumed that the initial velocity is 25m/s and throwing height is 1.8m. Under different throwing conditions, use computer to simulate of the movement trajectory of the javelin. Through comparative analysis, we obtained that the throwing range is different with different throwing angle. When the throwing angle is 45 degrees, the range reaches maximum with 68m. Finally, it uses gray model to predict the future javelin achievements trend, which can more scientifically and effectively guide the training of javelin throwers, providing theoretical support for the multi-faceted scientific research in this field. The study shows: the greater the javelin release speed is, the greater the horizontal throwing distance of javelin becomes. In the process of training and competition, it is necessary to speed up the javelin throwers' release speed through a variety of means; when there is no air resistance, the horizontal distance of the javelin throwing reaches the maximum usually in 45 degrees. Athletes have to go through a long-term training in order to achieve this effect. The horizontal distance of the javelin will also increase with the increase of the release height. Almost with each 1 millimeter rising, the horizontal distance has an increase of about 1 millimeter or so. In the javelin thrower selection, to choose tall athlete is also a necessary condition.

KEYWORDS

Computer simulation;
Throwing, gray prediction;
Model.

INTRODUCTION

Javelin throw develops early in our country. There are four people that have already broken through the 80 meters mark. Especially the women's event once was China's strengths; they have won the honor for our motherland in the World Series, so we should better sum up the experience of successful training and competition. Many scholars have carried through a lot of research on the final force action of javelin throwing. Especially in recent years, the application of three-dimensional photographic technique in scientific research makes people have a further understanding on the form and substance of the final force of Javelin throw. But there are still differences on the understanding of the final force action. Some scholars believe the last force

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is that right foot moves over support point from right hip after landing. It starts from the right foot pedal stretched before the left foot landed, and ends with the throwing javelin. Some other scholars believe that final force starts from the left foot (support foot) lands and from double support.

Although in recent years China has emerged Zhang Lianbiao, Li Rongxiang, Chen Qi, a group of outstanding men's javelin throwers, there is still a big gap away from the 98.48m world record created by Czech players Zeliezini and the 87.60m Asia record created by Japanese player Mizoguchi Kazuyo. This requires us to be based on reality, identify the problems of our javelin throwers, and try to narrow the gap from Asia and the world's athletes. Series of studies have shown that problems like throwing arm force in advance and force unreasonably of our athletes indeed exist. In the final analysis, our javelin throwers don not "delay" the Javelin and arm movements before the formation of "full bow", consequently phenomenon like force premature and wrong force order appear.

Based on the above issues, this paper mainly uses computer to simulate that in the same initial velocity conditions, with what throwing angle can reach the maximum distance. Finally, it builds gray model to predict the future javelin achievements trend, which can more scientifically and effectively guide the training of javelin throwers, providing theoretical support for the multifaceted scientific research in this field.

QUESTION ASSUMES

Assume that the air resistance is zero (or exclude the influence of air resistance);

The tilt angle and throwing angle of javelin are the same;

Assume that athletes do not have a particular disease or fatal injury, and physical quality is normal.

MODEL BUILDING AND SOLVING

The best throwing angle model of javelin

Javelin throwing can be taken as a inclined projectile motion. Projectile motion can be orthogonally decomposed into the uniform linear motion along the horizontal direction and vertical up-throw motion along the vertical direction. The angle between the objects throwing direction and the positive direction of X axis is called the projection angle, shown as θ . The maximum height that objects can reach is called throwing height; the horizontal distance from the throwing point to the landing point called throwing range. The inclined projectile moving object goes on uniform linear motion by the initial horizontal velocity in the horizontal direction; in the vertical direction it goes on vertical up cast motion by the initial velocity v_y ; oblique throwing motion curve is a symmetrical curve.

The mathematical analysis is as follows:

$$v_x = v_0 \cos\theta \qquad v_y = v_0 \sin\theta - gt \qquad x = v_0 \cos\theta * t$$

$$y = v_0 \sin\theta * t - gt^2/2 \quad t = 2v_0 \sin\theta / g$$

Wherein v_x is the horizontal initial velocity, v_0 is the projectile velocity, v_y is the vertical initial velocity, θ is the projectile angle, x is the horizontal range, y is the highest range.

The total displacement of the object in time t is as follows:

$$r = \sqrt{x^2 + y^2} = \sqrt{(v_0 \cos\theta \cdot t)^2 + (v_0 \sin\theta \cdot t - gt^2/2)^2}$$

Seen from the analysis, and only when $v_y = 0$, javelin reaches its highest point, and used-time $t = v_0 \sin\theta / g$; the time of javelin free falling from the highest point is the same with the required time rising to the highest point, so javelin flight time is $t = 2v_0 \sin\theta / g$.

Using matlab to draw the projectile trajectory as shown in Figure 1, the program code is as follows:

```
global location v0 alpha g;
options={'Initial position (coordinates)',' initial velocity v0',' projectile angle',' gravitational acceleration g',}; topic='seting';
lines=1;
def={'[0,0]','20','[0,45]','9.8'};
h=inputdlg (options,topic,lines,def);
location=eval (h{1});
v0=eval (h{2});
alpha=eval (h{3});
g=eval (h{4});
a=location (1);
b=location (2);
alfa=alpha*pi/180;
```

```
tEnd=v0*sin (alfa)/g+((v0*sin (alfa)/g)^2+2*b/g)^0.5;
t=linspace (0,tEnd);
x=v0*cos (alfa)*t+a;
y=v0*sin (alfa)*t-0.5*g*t.^2+b;
plot (x,y);
hold on
plot (x (100),y (100),'o')
xlabel horizontal distance/m
ylabel height/m
title projectile trajectory
```

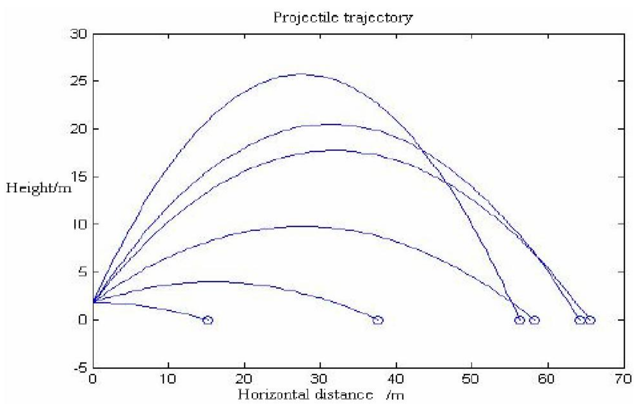

Figure 1 : Projectile trajectory drawn by matlab

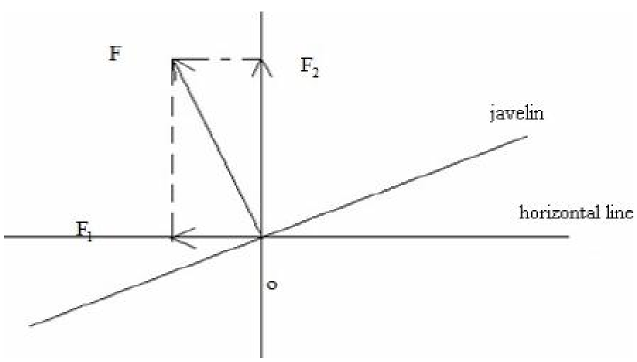

Figure 2 : Schematic diagram of force

Javelin results are mainly determined by shot initial speed of instruments. However under the considerable conditions in the race, the importance of throwing angle is very prominent, which reflects an athlete's or certain throw's technique condition. Javelin is a streamlined device with good gliding performance. Therefore in addition to the influence of inclined projectile motion, air also has a certain impact on javelin's flight. When javelin flights, it need to discharge part of the air laterally or push forward. Thus there is field that increases the air pressure in the front of the javelin, and vortex that makes the air form into irregular in the rear, which is known as the "turbulence" field. Javelin has a tilt angle of airflow. The join force (F) by air can be divided into vertical component and horizontal component (Figure 2). The horizontal component (F_1) is a frontal resistance, hinders the javelin flight forward, and needs energy consumption to overcome it. Since the vertical force component (F_2) has the effect of making the javelin rising, it extends the time that javelin glides in the air, which helps the improvement of the javelin performance. The most suitable attack angle is 8.2° on the basis of extensive experience and valid data.

Gray system GM (1, 1) model is aggregate data based on a variety of known factors in the system. Fitting this data time series by differential equations to approximate the dynamic process described by above time series, and then extrapolates to reach the purpose of prediction. This model obtained by fitting is the first-order differential equations of time series.

The gray system is to establish differential equations GM (1.1) for the discrete sequence.

$$\frac{dx}{dt}+ax=\mu \quad \text{GM (1.1)}$$

By the definition of derivative:

$$\frac{dx}{dt}=\lim_{\Delta t\to 0}\frac{x(t+\Delta t)-x(t)}{\Delta t}$$

When Δt is very small and take the approximation unit 1, then approximately have: $x(t+1)-x(t)=\frac{\Delta x}{\Delta t}$

Written in discrete form as:

$$\frac{\Delta x}{\Delta t}=x(k+1)-x(k)=\Delta^{(1)}(x(k+1))$$

Suppose the non-negative sequence is $X^{(0)}=\left(x^{(0)}(1),x^{(0)}(2)\cdots x^{(0)}(3)\right)$, conduct one-time accumulation to $X^{(0)}$ and obtain the generating sequence:

$$X^{(1)}=\left(x^{(1)}(1),x^{(1)}(2)\cdots x^{(1)}(3)\right)$$

Wherein:

$$x^{(1)}(k)=\sum_{i=0}^{k}X(i),\quad x^{(0)}(k)+az^{(1)}(k)=b$$

Simplified as:

$$x^{(0)}(k)=\beta-\alpha x^{(1)}(k-1)$$

Wherein:

$$\beta=\frac{b}{1+0.5a},\alpha=\frac{a}{1+0.5a}$$

$$\begin{bmatrix} x^{(0)}(2) \\ x^{(0)}(3) \\ \vdots \\ x^{(0)}(n) \end{bmatrix} = \begin{bmatrix} -\frac{1}{2}(x^{(1)}(1)+x^{(1)}(2)) & 1 \\ -\frac{1}{2}(x^{(1)}(2)+x^{(1)}(3)) & 1 \\ \vdots & \vdots \\ -\frac{1}{2}(x^{(1)}(n-1)+x^{(1)}(n)) & 1 \end{bmatrix}$$

$$Y = \begin{bmatrix} x^{(0)}(2) \\ x^{(0)}(3) \\ \vdots \\ x^{(0)}(n) \end{bmatrix}, B = \begin{bmatrix} -\frac{1}{2}(x^{(1)}(1)+x^{(1)}(2)) & 1 \\ -\frac{1}{2}(x^{(1)}(2)+x^{(1)}(3)) & 1 \\ \vdots & \vdots \\ -\frac{1}{2}(x^{(1)}(n-1)+x^{(1)}(n)) & 1 \end{bmatrix}$$

Performance prediction model

Use gray prediction method to predict the javelin achievements over the years; the javelin achievements of the Norwegian javelin thrower Andreas Tuoxierde over the years is shown in TABLE 1, TABLE 2 and TABLE 3. Using Matlab to predict the results, the program code is as follows:

```
x0=[85.31 85.26 88.37 86.83];
n=length (x0);
lamda=x0(1:4-1)./x0(2:4)
range=minmax (lamda)
x1=cumsum (x0)
for i=2:4
z (i)=0.5*(x1(i)+x1(i-1));
end
B=[-z (2:4)’,ones (4-1,1)];
Y=x0(2:4)’;
u=B\Y
x=dsolve (‘Dx+a*x=b’,’x (0)=x0');
x=subs (x,{‘a’,’b’,’x0'},{u (1),u (2),x1(1)});
yuce1=subs (x,’t’,[0:5]);
digits (6),y=vpa (x)
yuce=[x0(1),diff (yuce1)]
epsilon=abs (x0-yuce)
delta=abs (epsilon./x0)
a=min (epsilon);
b=max (epsilon);
p=0.5;
s=epsilon+p*b;
glxs=(a+p*b)./s;
gldu=sum (glxs)/n
pjz=sum (x0)/n
pf1=(x0-pjz).^2
s1=sqrt (sum (pf1)/(n-1))
deta=sum (epsilon)/n;
pf2=(epsilon-deta).^2;
s2=sqrt (sum (pf2)/(n-1))
C=s2/s1
s0=0.6745*s1
ek=abs (epsilon-deta)
```

Use the athlete’s javelin achievements of year 2004-2007 in TABLE 1 to forecast the javelin achievements of year 2008-2009, the result is shown in TABLE 3.

TABLE 1 : The javelin achievements of year 2004—2007

Year/achievements	Achievements (meters)	Average achievements (meters)
2004	86.5、84.12	85.31
2005	85.18、86.13、85.29、85.44、84.13、84.44	85.26
2006	89.50、89.78、90.13、84.98、85.18, 87.43、86.97、90.34、90.59	88.37
2007	89.51、88.36、86.14、86.28、87.79、80.71、89.49、86.39	86.83

TABLE 2 : The javelin achievements of year 2008-2009

year/ achievements	Achievements (meters)	Average Achievements (meters)
2008	87.73、.85.19、87.59、90.57	87.778
2009	89.50	89.50

According to the results in TABLE 3, get Figure 3 and Figure 4 by means of Excel:

Figure 3 shows the fold line of the athlete’s actual values and predicted values in year 2004-2009. Seen from the two fold lines’ intensive degree, the actual values and predicted values can have good combination, and can have a good fitting result. Figure 4 is the fold line chart of the predicted values and the actual values. We can see from Figure 4 that the error rate is gradually reducing over time, which indicates that the prediction is effective.

TABLE 3 : Comparison table of the predicted achievements with actual achievements

Year/ achievements	Predicted Achievements (meters)	Actual Achievements (meters)	Error rate
2004	85.3100	85.31	0
2005	86.0426	85.26	0.918%
2006	86.8171	88.37	1.757%
2007	87.5986	86.83	0.885%
2008	88.3872	87.78	0.692%
2009	89.1828	89.50	0.354%

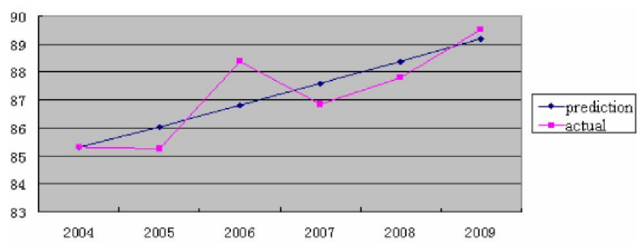

Figure 3 : Actual and predicted values of year 2004 - 2009

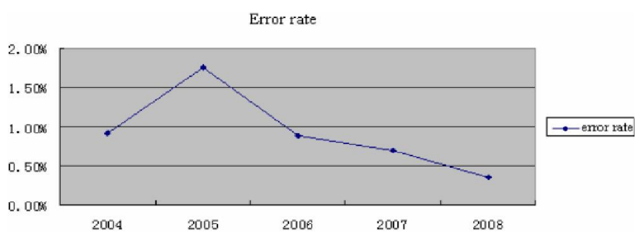

Figure 4 : The error rate between the predicted value and the actual value

CONCLUSIONS

The greater the javelin release speed is, the greater the horizontal throwing distance of javelin becomes, and the impact is much more obvious. In the process of training and competition, it is necessary to speed up the javelin throwers' release speed through a variety of means.

When there is no air resistance, in the case of the same release speed, the horizontal distance of the javelin throwing will correspondingly increase with the increase of the release angle. Usually when the angle is 45 degrees, the horizontal distance of the javelin throwing reaches the maximum. In the training process, it is necessary to let athletes maintain proper release angle. One has to go through a long-term training in order to achieve this effect.

Under the circumstances that release speed and release angle are the same without angle of attack and there is no air resistance, the horizontal distance of the javelin will also increase with the increase of the release height. Almost with each 1 millimeter rising, the horizontal distance has an increase of about 1 millimeter or so. In the javelin thrower selection, to choose tall athlete is also a necessary condition.

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