Research on Location Problem Based on the Sun Shadow

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Abstract. In this paper, we study the problem of solar shadow positioning in the National Mathematical Modeling Contest in 2015, A.This paper established mathematical model of the change in length of the shadow, analysis of the length of the shadow of each parameter, and used to establish the model of painting from October 2015 between 22 Beijing time 9:00-15:00 Tian'anmen Square (latitude 39 degrees 54 minutes 26 seconds, longitude 116 degrees 23 minutes 29 seconds) 3 meters straight rod of sun shadow length curve.

1. Introduction

The sun shadow positioning technology is through the analysis of the sun shadow change video objects, a method to determine the location and date of the video shoot. We first establish mathematical model of the change in length of the shadow, and then analyzes the shadow length on each parameter variation, and used to establish the model of painting from October 2015 between 22 Beijing time 9:00-15:00 Tian'anmen Square (latitude 39 degrees 54 minutes 26 seconds, longitude 116 degrees 23 minutes 29 seconds) 3 meters straight rod of sun shadow length curve.

2. The Model

2.1.Establishment of model

Through the analysis, we can know that the solar zenith angle is the determining factor of the shadow length, and the angle of time, latitude and longitude of latitude influence the size of the height of the sun. The three angles respectively, indicating that the seasonal changes, time changes and the observation point location changes, so according to these factors, we can establish mathematical model of the change in length of the shadow, to determine the variation of the solar elevation angle, get different time segment internal fixation object height sun shadow length curve.

The change of the shadow length of the object under the sun light is illustrated with a fixed straight bar as an example. Set the height of the sun angle is α ,the weft insertion angle is δ ,the time angle is ω ,the geographical longitude of the observation site is ψ (east longitude is position,west longitude is negative),Geographical latitude is φ (north latitude is position,south latitude is negative),The expression of [1] the solar height angle is

$$\sin\alpha = \sin\varphi\sin\delta + \cos\varphi\cos\delta\cos\omega \qquad (2.1)$$

The latitude of the latitude of the sun is a point of view with the change of the date.To refer to the literature [2], we can know that the formula for calculating the size of the weft angle is

$$\delta = 23.45\times\sin\left(\frac{2\pi\times(284+n)}{365}\right) \qquad (2.2)$$

Among them, n is the number of a year in a year.

The calculation time angle starts at 12 noon,and the angle is $0°$,The number of changes per hour is $15°$ .In order to obtain the time of observation of a certain moment, according to the world time zone division, we need to add the difference between the reference time zone and the longitude of the observation. Thus, the calculation formula for the time angle size is

$$\omega = (12-t)\times 15° + (\psi_0 - \psi) \qquad (2.3)$$

In the formula, ψ_0 is the geographical longitude of reference time zone , t is the time of reference time zone,Unit is an hour.According to the trigonometric function relation between the height of the sun and the height of the straight bar and the shadow, we can get :

$$\cot\alpha = \left(\frac{l}{h}\right) \qquad (2.4)$$

In the formula, h is the Height of straight rod, l is the The length of the straight rod of the sun.

Directly, the length of the straight rod is only related to the height of the sun. From the 2.1 type ,we can know that the solar zenith angle α is related to the latitude angle δ and the time angle ω is related to the geographical latitude φ of the observation area.And according to 2.3, 2.2 type can be known, δ is related to the date n and ω is related to the time t and longitude ψ .As a result, the length of the solar shadow varies with time and location.

2.2.Result

In order to determine the condition of the subject under the shadow of the change curve, we need to bring the known value to the above formula to solve. Calculated, in October 22, 2015 the corresponding date is $n = 295$ .The geographical latitude of the Tian'anmen square is $\varphi = 39.907°$,Geographical longitude is $\psi = 116.391°$ .The straight rod location of the reference time for the Beijing time,that is $\varphi_0 = 120°$ .Above statement and subject condition, and $h = 3$,by using MATLAB program, we can get the smooth curve of the length of the straight bar with the time variation of 9 to 15. The shadow curve is shown in figure 1, and the length of the some image is shown in table 1.

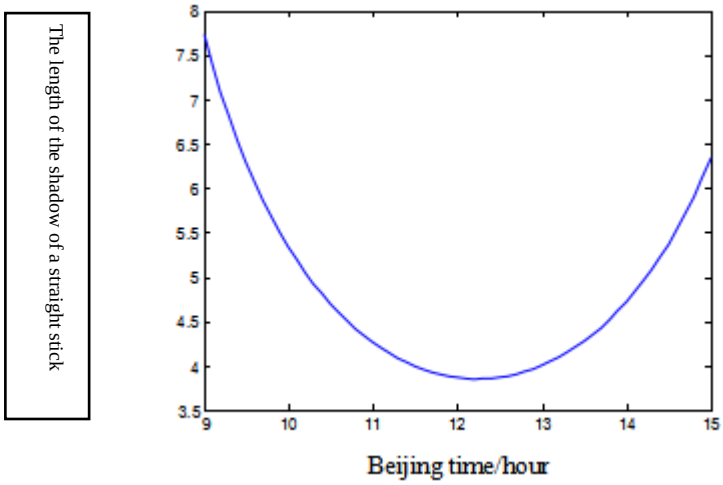

Figure 1 The curve of the length of the straight bar with time

Table 1 The length of the straight rod of the sun at different times

Time	9	10	11	12	13	14	15	
Shadow length		7.7379	5.3337	4.2529	3.8550	3.9910	4.7070	6.3298

Observation of the image can be found, Beijing time at nine o'clock, Tian'anen observation of the largest shadow length and it is 7.7379 meters.And Beijing time 12:00 noon always, Tian'anmen Square straight rod sun shadow length did not reach to the shortest.This is because the longitude of the Tian'anmen square and the longitude of the Beijing time is different, resulting in local time and Beijing time difference .We can use MATLAB program, the approximate estimate the shadow length of the shortest time corresponding to the Beijing time, also can use the known Tian'anmen Square longitude (east longitude 116 degrees 23 minutes 29 seconds) to complete the solution.

The longitude of the Tian'anmen square is ψ_T ,the time of local is t_T ,So,

$$t_T = \frac{(\psi_T - \psi) \times 4}{60} + 12$$

We can get: $\psi_T = 116.391°$, $t_T = 12.241$, the length of the shadow is 3.8401 meters.

3. Conclusion

In daily life, we can observe that the length of the shadow of the light is changing with the change of the light source and the space position of the object. When the sunlight is used as the light source, the position of the sun moves, which influences the size of the height of the sun, which causes the change of the length of the shadow.And the size of the solar altitude angle can be different from the different observation time and the latitude and longitude of the observation. Therefore, in the case of the height of the known object, the latitude and longitude can be determined, and the length of the shadow of the object at different times in the light of the sun can be determined.

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