Research on the Velocity and Position Solution of Dragon Dance Team Based on Helical Motion Mechanism

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Abstract. The Panlong custom is prevalent in the southern provinces and cities of the annual event and contains a deep regional culture, its movement can be seen as a multi-jointed chain along the isometric spiral. The seemingly simple form of screw coil entry in the dragon dance movement requires precise control of the speed and position of each handle to achieve a complex movement that is beautifully coordinated. Herein, this study constructed the mapping function of the front handle coordinates of the dragon's head about time searched and approximated the position of the back handles using the dichotomy method, solved the velocity transfer relationship between the front and back two handles, and according to the established chain iteration model of the dancing dragon's plate entry, the positions and velocities of the individual handles were solved sequentially backward, and the positions and velocities of each handle were obtained within 300s. If the two handles of the bench are traveling along a curve with continuously changing curvature, the linear velocity of the handles increases in the direction of increasing curvature. When coiling along the spiral, the direction of coiling is the direction of growing curvature, so the velocity of the dragon's head is the maximum value of the whole coiling velocity.

Keywords: Mechanism analysis, Chained iterative model, Dichotomy, Orthogonal decomposition.

1. Introduction

Since joining the Convention for the Safeguarding of the Intangible Cultural Heritage in 2004, more than 100,000 representative items of China's intangible cultural heritage have been included, and its efforts and achievements in safeguarding the culture are evident to all [1]. Among them, as a big annual event commonly found in southern provinces and cities, the Panlong (also known as the Bench Dragon) contains a profound regional culture, is a spectacular and lively spectacle, and is loved by the people. As an important part of traditional Chinese culture, dragon dance has a long history and rich cultural connotations. In the dragon dance performance, the dragon dance team realizes various complex movements of the dragon body through coordination and cooperation, in which the screw thread coiling in, as a common and classic form of performance, not only has an important impact on the overall aesthetics of the dragon dance team but also involves the complex mechanics and laws of motion. In the performance, the dragon dancers carry out a spiral march by lifting the plate, so that the dragon body shows a trajectory similar to that of a screw thread. This process may seem simple, but it requires precise control of the speed and position of each handle to ensure the coordinated movement of the dragon's body.

With the development of modern technology, mechanical analysis, and motion simulation in the dragon dance movement have gradually become a research hotspot. In this study, firstly, according to the expression of the solenoid as well as the relationship between the velocity and the angular velocity, the mapping function of the coordinates of the handles in front of the dragon head concerning the time is constructed; secondly, the position of the latter handles is qualified according to the spacing of the two handles and other conditions, and the bisecting method is utilized for searching and approximation of the position of the latter handles; and next, according to the position of the two handles in the solenoid and the orthogonal decomposition principle, the velocity transfer relationship between the two handles before and after is solved; finally, according to the established chain iterative model of the dancing dragon disk in, the calculation starts from the handle in front of the faucet, and the loop iteration is carried out [2]. The positions and velocities of the individual handles are solved sequentially backward.

2. Modeling the Spiral Motion of a Dragon Dance Team

The data for this study was obtained from www.mcm.edu.cn. The data is given the spiral line that the dragon dance team coiled into the initial position of the dragon head, and the position and speed of each handle at each moment when the speed of the dragon head is 1m/s is solved. After analyzing the traveling mechanism of the dragon dance team, it can be seen that counting from the front handle of the dragon head, the position and speed of each handle are directly related to the position and speed of the previous handle, and it is only necessary to determine the position of the dragon head at each moment, and then obtain the relationship between the position and speed of each handle and the previous handle. Then it can be chained backward sequentially to get the position and speed of all the handles. The flow chart is shown in figure 1.

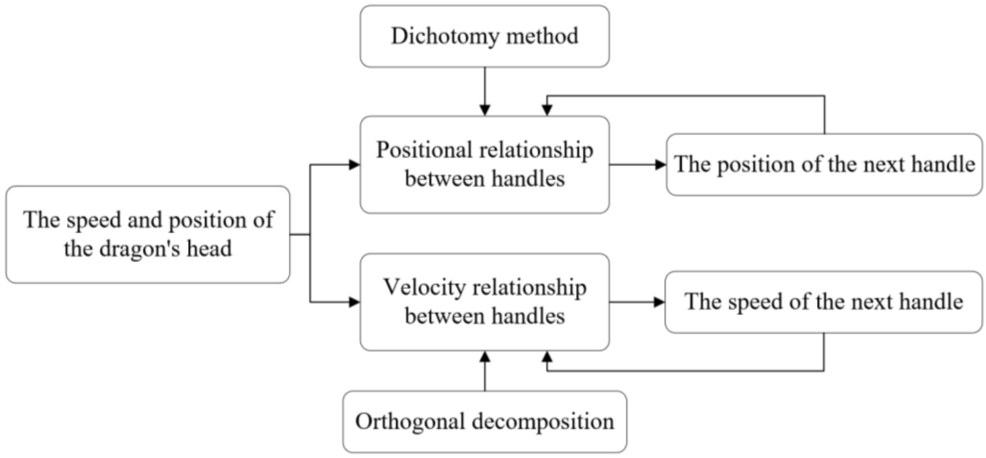

Figure 1. Flowchart of the solution

2.1. Equation for determining the position of the front handle of the faucet at each moment

Establish a two-dimensional planar coordinate system and use polar coordinate equations to represent the solenoid [3]:

$$r = a \cdot \theta + b \tag{1}$$

Where, a is the pitch coefficient, indicating that each unit increase in the angle θ of the helix corresponds to the corresponding increase in the value, in this question to take "0.55/2π"; b is the initial radius (the corrected distance between the center of the helix and the origin), in the problem in the coordinate system of zero.

The front handle of the faucet plate (later called the faucet handle) is always located on the screw thread, and the linear velocity v_0 remains the same, in this question take v_0 = 1m/s. Remember that the faucet handles polar coordinates are expressed as (r_h, θ_h). First of all, you can determine the angular velocity of the faucet handle in the screw thread motion by the relationship between the linear velocity and the angular velocity in the following equation:

$$v = -r \cdot \omega \tag{2}$$

Joining (1) and (2) the angular velocity w can be expressed as:

$$\omega = -\frac{v}{r} = -\frac{1}{a \cdot \theta} \tag{3}$$

Requiring the coordinates of each moment of the solution faucet handle, the relationship between θ_h and time can be established, based on the fact that angular velocity is the rate of change of an angle:

$$\omega = \frac{d\theta}{dt} \tag{4}$$

Simultaneous equations can be obtained:

$$\theta\, d\theta = -\frac{1}{a} dt \tag{5}$$

The differential equations were solved using separated variables combined with integrals to obtain [4]:

$$\frac{\theta^2}{2} = -\frac{t}{a} + C \tag{6}$$

Where C is the constant of integration concerning the initial conditions, and let the angle θ_h = θ_0 be known at the initial moment:

$$C = \frac{\theta_0^2}{2} \tag{7}$$

Ultimately, the equation for the angle as a function of time can be solved as:

$$\theta(t) = \sqrt{\theta_0^2 - \frac{2t}{a}} \tag{8}$$

Here, $\theta_0 = 16 \times 2\pi$

Substitute different time t into equation (8) to calculate the θ_h at this time, and then substitute it into the screw equation, the position coordinates of the faucet handle at this moment can be determined.

2.2. Dichotomous solution for each handle position

The benches carried by the dragon dance team are all rectangular wooden boards, the board length of the dragon head is l_h =3.41m, the board length of the dragon body and the dragon tail is l_b =2.2m, and their widths are w =0.3m. There are connection holes at the front and back of the benches, which are inserted into the handles for the first and last connections, and the connection holes are 27.5cm away from the head of the boards, and the hole diameters are 5.5cm, and the centers of the various handles (i.e., the centers of the connection holes) are located on the screw lines in the dragon process as shown in figure 2. The center of each handle (i.e., the center of the connecting hole) should be kept on the screw line during the traveling of the disk dragon, as shown in figure 2.

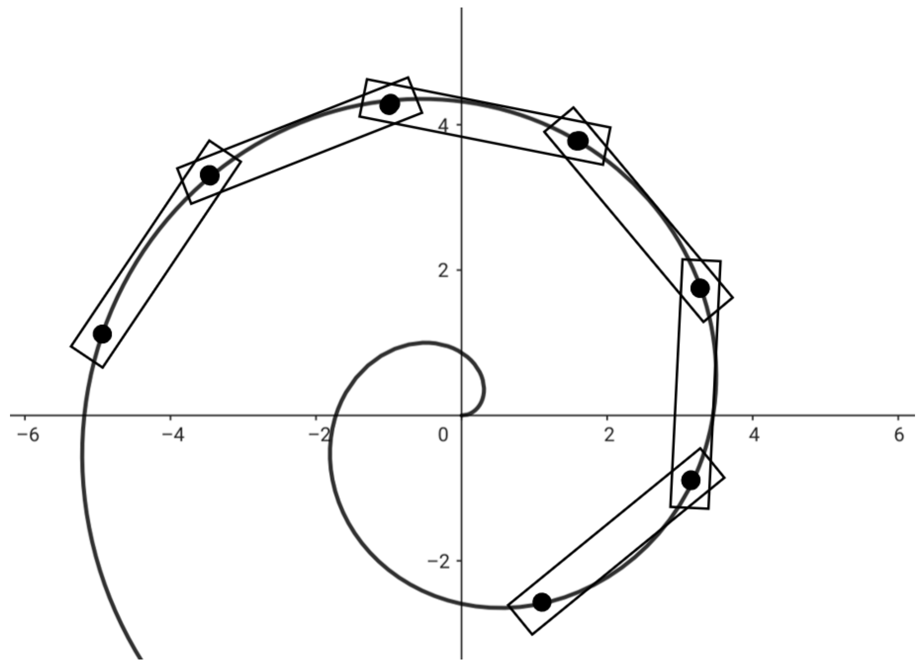

Figure 2. Schematic diagram of the traveling of Panlong

Mark the center distance of the two connecting holes d (later called hole spacing), the distance between the holes in the dragon's head d_h = 2.86m, and the distance between the holes in the dragon's body and the dragon's tail d_b = 1.65m. as shown in figure 3.

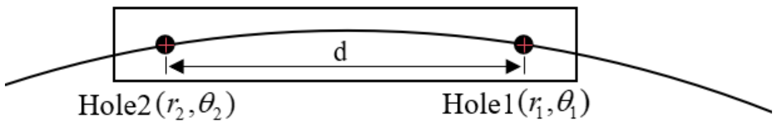

Figure 3. Schematic diagram of hole spacing

According to the analysis, the position of the latter point is directly related to the position of the former point, if the position of the former point is known, it can be combined with the equation of the solenoid and the equation of the distance between the two points to solve for the position of the latter point as follows:

The two handles on the same board are referred to as Handle 1 and Handle 2, with Handle 1 being closer to the faucet and represented by polar coordinates (r_1, θ_1), while Handle 2, which is closer to the tail, has coordinates (r_2, θ_2). The straight-line distance between these two points is the hole spacing d. To ensure that the centers of the two handles are located on the screw line, their coordinates must satisfy the following:

$$\begin{aligned} r_1 &= a \cdot \theta_1 \\ r_2 &= a \cdot \theta_2 \end{aligned} \tag{9}$$

The hole spacing needs to satisfy the following equation:

$$d = \sqrt{r_1^2 + r_2^2 - 2 \cdot r_1 \cdot r_2 \cdot \cos(\theta_2 - \theta_1)} \tag{10}$$

The equation can be obtained by associating equation (9) with equation (10):

$$d = \sqrt{\theta_1^2 + \theta_2^2 - 2 \cdot \theta_1 \cdot \theta_2 \cdot \cos(\theta_2 - \theta_1)} \tag{11}$$

If the coordinates of Hole 1 are known, the coordinates of Hole 2 can be calculated by bringing the known quantity into equation (11). However, for equation (11), which is a nonlinear equation that needs to be solved using a numerical method, the bisection method is chosen here for the iterative calculation of the solution [5]. First of all, the arc length between the solenoids corresponding to holes 1 and 2 can be expressed as:

$$S = a\int_{\theta_1}^{\theta_2} \sqrt{t^2+1}\, dt \tag{12}$$

Where t denotes the radian.

In this paper, the arc length S is limited, according to the analysis, its upper limit should not exceed half of the coil, otherwise, there will be a collision problem, to simplify, this paper will be approximated as a circle for the coil; its lower limit is 0. The following formula:

$$S \in [0, 2\pi d] \tag{13}$$

The computational procedure for the bisection method is:

(1) Take a value in the range of S and bring that value into equation (12) to solve for T;

(2) Take T into equation (11) and solve for the chord length at this point;

(3) Compare this chord length with the hole spacing. If it is too long, return to step 1, take a smaller S, and repeat the step; if it is too short, return to step 1, take a larger S, and repeat the step; if it is equal (the error is within the acceptable range), return to the θ_2 in that cycle.

In this way, the positional relationship between Hole 1 and Hole 2 can be solved.

2.3. Velocity solution based on orthogonal decomposition

According to the mechanism of the hinge moving along the curve, it can be seen that two points on the same plate have equal velocity components on the plate [6]. As shown in figure 4.

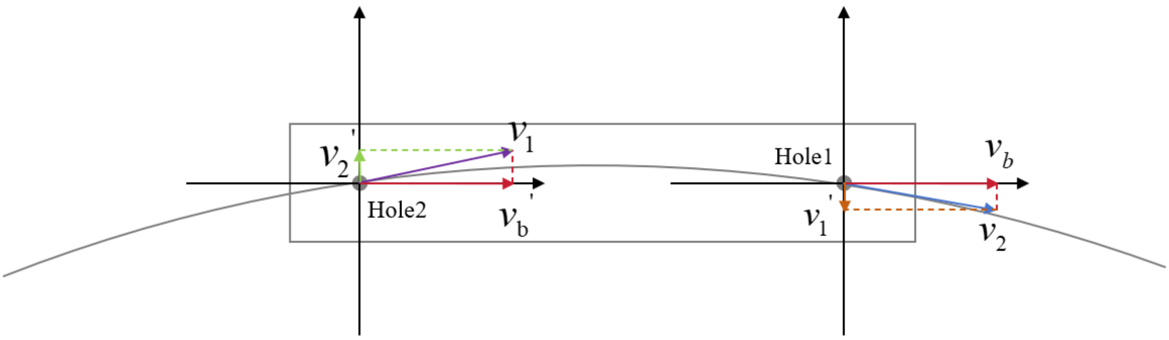

Figure 4. Schematic diagram of velocity decomposition

Let the hole 1 linear velocity be v_1 and the hole 2 linear velocities be v_2, which are respectively cross-decomposed along the plate direction and perpendicular to the direction of the plate, the obtained $v_b = v_b'$. Next, the solution is based on this principle, and the procedure is as follows:

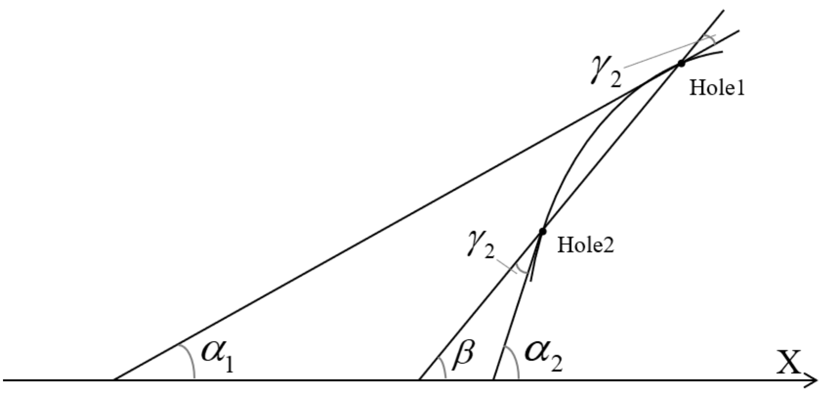

Figure 5. Schematic diagram of velocity decomposition angle

As shown in figure 5, the angle between the velocity direction of hole 1 and the x-axis is α_1, the angle between the velocity direction of hole 1 and the x-axis is α_2, the angle between the two holes' connecting lines and the x-axis is β, the angle between the velocity direction of hole 1 and the two holes' connecting lines is γ_1, and the angle between the velocity direction of hole 1 and the x-axis is γ_2, which can be known from plane geometry:

$$\begin{aligned}\gamma_1 &= \alpha_1 - \beta \\ \gamma_2 &= \alpha_2 - \beta\end{aligned} \tag{14}$$

Combined with the velocity decomposition shown in figure 5, this can be found [7]:

$$\begin{aligned}\overrightarrow{v_b} &= \overrightarrow{v_1} \cdot \cos\gamma_1 \\ \overrightarrow{v_b} &= \overrightarrow{v_2} \cdot \cos\gamma_2\end{aligned} \tag{15}$$

The coupling then solves for the velocity relationship between hole 1 and hole 2.

3. Results and discussion

First of all, according to the previous solution, solve the position coordinates of the handle of the dragon's head at each moment; at a certain moment, take the handle of the dragon's head as the first known coordinates, and substitute into the position relationship between the two handles of the solution, and then carry out calculations backward, so that we can get the position coordinates of all handles; at a certain moment, take the handle of the dragon's head as the first known linear velocity, and then substitute into the velocity relationship between the two handles of the solution, and then carry out calculations backward. At a certain moment, take the head handle of the dragon as the first known linear velocity, substitute into the velocity relationship between the two handles, and then carry out the calculation to find the linear velocity of all handles.

Using the obtained results, the schematic diagrams of the disk dragon at 60s and 240s are plotted as shown in figure 6 (a) and (b):

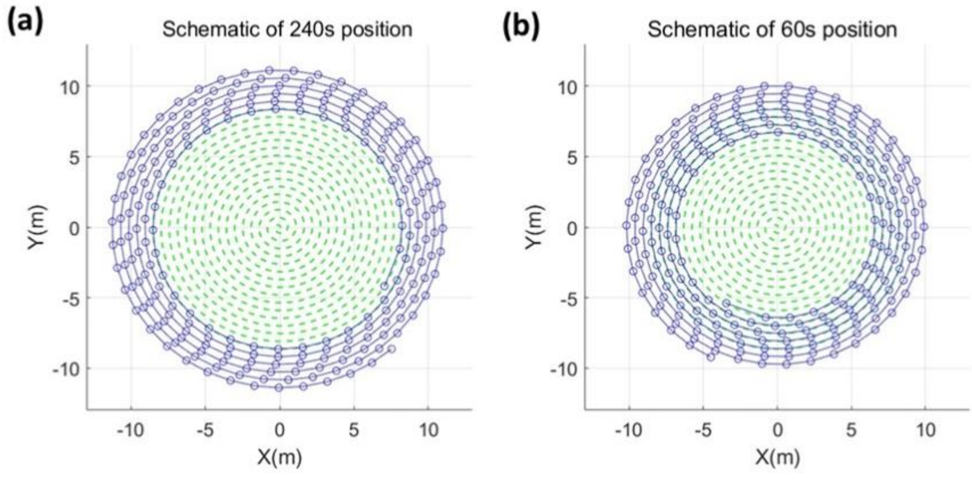

Figure 6. Schematic diagram of the results of the disk-in position. (a) 60s position schematic; (b) 240s position schematic

From the figure, it can be observed that, except for the faucet, the length of each bench is uniform, and the centers of the handles are positioned on the screw line, aligning with the actual circumstances. In terms of the period, it is evident that the degree of disking at 240 seconds is greater than that at 60 seconds, conforming to the correlation between the degree of disking and the progression of time. The results obtained from the solution are satisfactory.

Using the results obtained, the velocity distribution of each handle at 60s and 240s is plotted as shown in figure 7 (a) and (b):

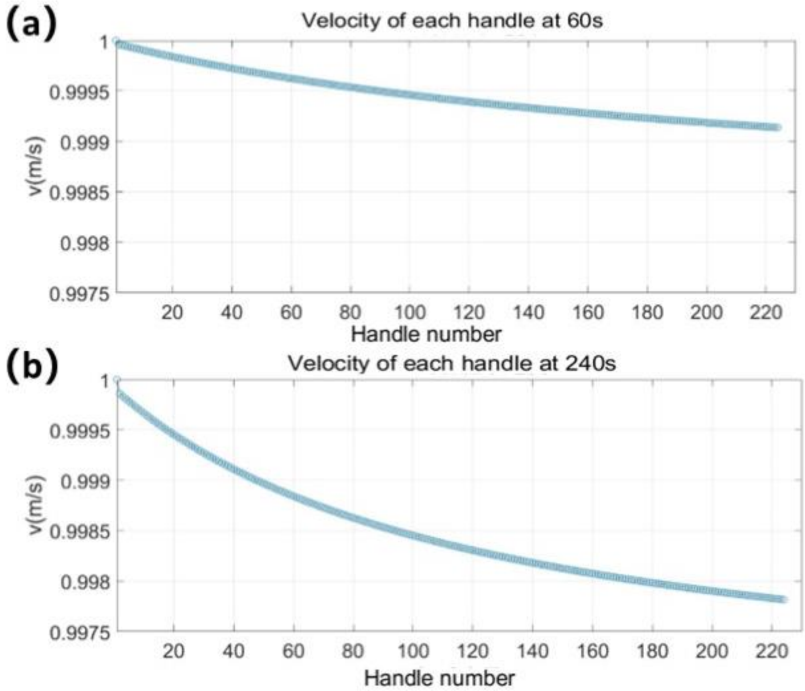

Figure 7. Schematic diagram of the results of the disk-in speed. (a) Velocity plot of each handle at 60s; (b) Velocity plot of each handle at 240s.

As shown in figure 7(a), at sixty seconds, the disk dragon is located outside the solenoid; the closer the solenoid is to the outer ring, the smaller the velocity change due to the radian at the same chord length, so the curve in (a) is gentler, and the curve in (b) is steeper in the first section and tends to be flatter in the latter section. Because the dragon's head bench is longer, there is a sudden change under both moments when the velocity changes in the first segment, while the dragon's body board lengths are all equal and the velocity changes are more uniform. Through the velocity relationship between the two points can be deduced that if the two handles of the bench are traveling along the curve of continuous change of curvature, the linear velocity of the handles will increase with the direction of increasing curvature. When coiling in along the spiral, the direction of coiling in is the direction of increasing curvature, so the velocity of the faucet is the maximum value of the whole coiling velocity [8]. All the above features show that the results of this solution are by the actual situation and the results are good.

4. Conclusion

Firstly, the mapping function of the coordinates of the front handle of the dragon's head concerning time is constructed according to the expression of the solenoid and the relationship between the velocity and the angular velocity[9]; secondly, the position of the rear handle is qualified according to the spacing of the two handles, and the position of the rear handle is searched and approximated by using the bisection method[10]; next, the velocity transfer between the front and rear handles is solved according to the position of the two handles in the solenoid and the principle of orthogonal decomposition. Finally, according to the established chain iteration model of the dragon dance, starting from the front handle of the dragon's head, the loop iteration, and then solving the position and velocity of each handle, the position and velocity of each handle in 300s are obtained. From the solved results, it can be seen that, except for the dragon's head, the length of each bench is uniform, and the center of the handles are located in the screw line, which is in line with the actual situation; from the period, the degree of disking in at 240 s is larger than that of 60 s, which is in line with the relationship between the degree of disking in and the change of the time, and the results of the solution are good.

This paper provides a research idea and framework applied in the field of kinematic analysis to solve the problem of how to accurately control the speed and position of the handles in the dragon dance movement to realize the coordinated and beautiful complex movement, and the feasibility of the method is proved by constructing the chain iterative model of the dragon coiling in.

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