EasyChair Preprint

№ 174

The modeling and implementation of Non- rigid motion based on the carcass traits

Shutian Fang, Zhehao Xu, Hanqi He and Qiyun Zheng

EasyChair preprints are intended for rapid dissemination of research results and are integrated with the rest of EasyChair.

May 25, 2018

The modeling and implementation of non-rigid motion based on the carcass traits

Shutian Fang, Zhehao Xu, Hanqi He, Qiyun Zheng [1]
YK PAO School, Shanghai, China

Abstract. Unmanned aerial vehicle (UAV) group of the air show is the most popular show nowadays, but it exists the shortage of the display and the image. The article is based on the bionic movement of the dragon as the experiment object. This article investigates on the image scatter sample processing, multi-link device rotation system technology such as 3d rotation transformation. Ultimately, on account of the characteristic of skeleton, the method constructs the complex and non-rigid images, both of three-dimensional motion model and plan trajectory model. The result of the MATLAB simulation is vivid, and thus, the method discussed in this article provides a general solution for unmanned aerial vehicle (UAV) air shows.

Keywords: UAV Aerial Show, non-rigid motion, carcass traits, three-dimensional motion model, trajectory model

1.1 Introduction

Since Intel Corporation has achieved the Intel® Shooting Star ™ [1]formation flight show and created a stunning nighttime aerial landscape , the flight control system of the unmanned aerial vehicle (UAV) group of air show is widely utilized at Arts, Entertainments, and festivals, giving credits to its precise control of the graphic shave, various ways of presenting artistic visual effects and good features of environmental protection.

Its core technology is designing and operating the flight of UAVs according to the coordination of every point and motion functions in the image. Therefore, most of the motion models, which is the analysis for image characters, can be materialized.

In real life, some ordinary designing schemes for unmanned air show images are always two-dimensional, such as alphabets, numbers, and etc., and it is rare to

[1] Shutian Fang, e-mail: s17515@stu.ykpaoschool.cn
Zhehao Xu, e-mail: s13036@stu.ykpaoschool.cn
Hanqi He, e-mail: s13015@stu.ykpaoschool.cn
Qiyun Zheng, e-mail: s15583@stu.ykpaoschool.cn
YKPAO School, Shanghai, China

have irregular images to be displayed, and furthermore, the irregularly three-dimensional motions simply haven't been reported yet.
The foundation of the model is investigating the skeletal characteristics and the complex motion of non-rigid images in a horizontal trajectory carcass traits. Taking the bionic movement of the dragon as an example, based on the foundation, this article is building models to the non-rigid and three-dimensional objects moving in a trajectory and materializing the process in the MATLAB. Its particular achievement is that the model can be applied to any image of unmanned aerial vehicle (UAV) air show.
Moreover, the key technology of the scheme includes the image preprocessing, the motion's fixed points, skeleton construction, skin adhesion, flat trajectory and 3D rotation trajectory analysis, and etc.

1.2 Related Work

In this article, the purpose of image preprocessing is to remove the noise and edge glitches in the original input image, thus to obtain the clear image edge and better scatter sampling at the edge of the image, and therefore to determine the position and quantity of the UAVs. The result by processing the output image through the above steps is shown in Fig. 1.
Step1： transform the input images into a grayscale image[3], and acquire a binary image by using the threshold transformation method[4], and then invert the binary image.
Step2： Use the linear spatial filter function[5][6] to filter the image and remove the noise points. And use the smoothing function[7] to remove the glitches at the edges of the image in the meantime;
Step3： Use the Gonzalez's boundary function [8][9] [8][9]to extract the contour in a binary image;
Step4： Use the Gonzales bsubsamp function[10] [10] to subsample the outline boundaries and therefore get the scatter distribution on the image boundaries.



（a）The original input image

(b)An image boundary map obtained by binarizing, inverting, and smoothing

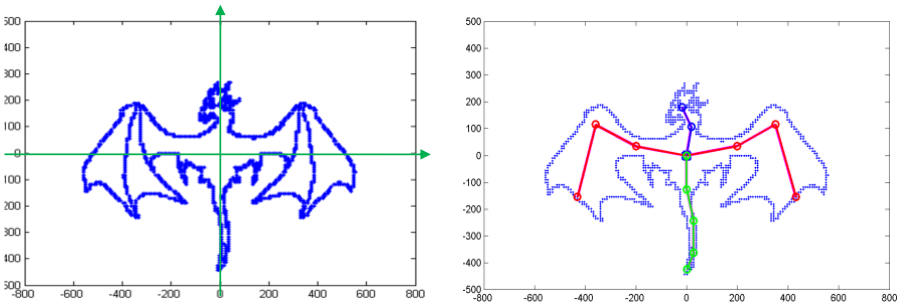
(c) Scatter plot obtained by Subsampling the border

Fig 1. Effect of image preprocessing

1.3 The modeling of non-rigid motion in complex image plane

The dragon is an odd object. The movement of various joints, which is a typical non-rigid motion, makes the moving pattern more complicated to analyze.
In order to solve this problem, we firstly simplify the linkage of the dragon's bones and joints to a multi-link system[11]. Therefore, the next key issue is to select the key points in the skeleton and re-establish the multi-link system. Before constructing the movement model, we need to firstly determine the plane coordinate system of this object.

1.3.1 Plane coordinate system



(a) dragon's outline coordinates (b) The key point of the dragon and its skeleton

Fig 2. Outline points and skeleton of the dragon

In order to coordinate the dragon’s movement in the air properly, we took the graphic center of the dragon’s body as the fixed point. And we established the 2-dimensional coordinate system with this fixed point as the origin and each point in the outline is calculated and shown as in Fig 2(a).

1.3.2 The moving trajectory of non-rigid motion

We divide the planar motion model into two steps. First of all, it sets up a multi-link device rotation model for the skeleton trajectory. On this basis, the complete two-dimensional trajectory of complex images is constructed by implementing the adhesion of the skin. For below, the steps to achieve the trajectories of skeleton motion are listed.

Step1： Pin the 13 key points in the coordinate system and set up coordinates graph for dragon skeleton: points that are related to the head movement, the trunk movement, the wing movement and the tail movement. Then the points are collected in a chart. The coordinate chart is shown in the Table 1. The figure, comprising key points and coordinates, is shown in Fig 3.

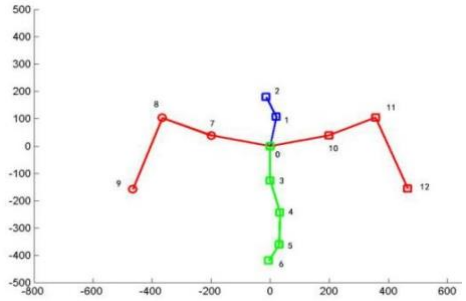


Fig 3. keel key point label

table 1. The sequence of key points involved in the movement of each component

Sports branch	Key point sequence
Head movement	0-1-2
Body movement	0-1,0-3
Left wing movement	0-7-8-9
Right wing movement	0-10-11-12
Tail movement	0-3-4-5-6

Step2： Separate every motion and render the motion track. Taking the right wing for instance, the detailed process is listed：

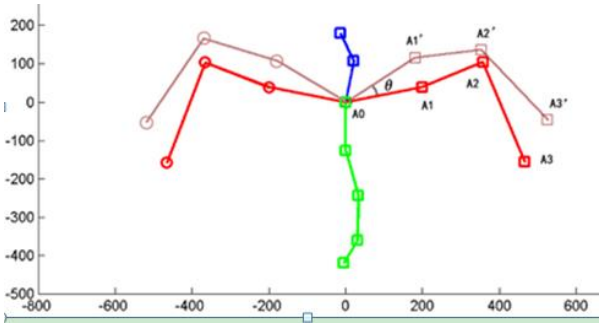


Fig 4. the rotative diagram of right-wing skeleton

As shown in figure 4, dragon's right wing has 4 key points A_0, A_1, A_2, A_3 which form a three-joint link system, and takes A_0 as the fixed point. Firstly, A_1, A_2, A_3 makes a rotation around A_0 and this is defined as the movement Z_1; then, A_2, A_3

makes a rotation around A_1 which defined as the movement Z_2; finally, A_3 makes a rotation around A_2 which is defined as the movement Z_3; thus a new coordinates of A_1, A_2, A_3 are marked as A_1', A_2', A_3'. The mathematical relationship between them can be described as

$$\begin{cases} A_1' - A_0 = Z_1(A_1 - A_0) \\ A_2' - A_1' = Z_2 Z_1(A_2 - A_1) \\ A_3' - A_2' = Z_3 Z_2 Z_1(A_3 - A_2) \end{cases} \quad (1)$$

In this case, $Z_i (i = 1,2,3)$ is the rotation variation matrix[12], namely

$$Z_i = \begin{bmatrix} \cos\theta_i & -\sin\theta_i \\ \sin\theta_i & \cos\theta_i \end{bmatrix} \quad (2)$$

In this case, θ_i is a counterclockwise rotation angle. The motion track of the key points can be derived by (2)

$$\begin{cases} A_1' = Z_1(A_1 - A_0) + A_0 \\ A_2' = Z_2 Z_1(A_2 - A_1) + Z_1(A_1 - A_0) + A_0 \\ A_3' = Z_3 Z_2 Z_1(A_3 - A_2) + Z_2 Z_1(A_2 - A_1) + Z_1(A_1 - A_0) + A_0 \end{cases} \quad (3)$$

Step3: Following up the similar procedure in the step 2, each of the motion track of the head, trunk and wings are deduced, and the motion track of the synthesized skeleton is obtained, as shown in Fig5.

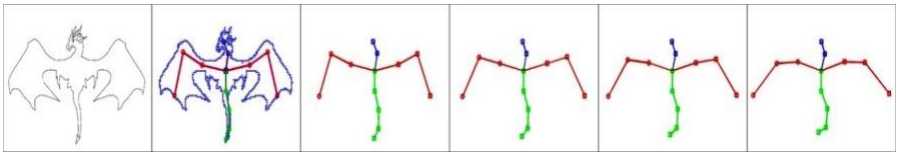
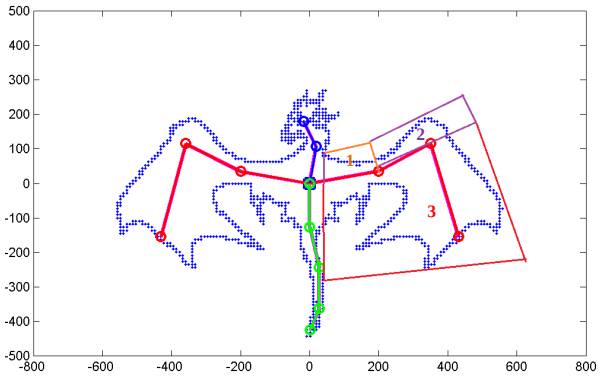


Fig 5. Dragon skeleton kinematic trajectory

1.3.3 skin attachment model

We define the drones which synchronize the movement of the skeleton as the outline attachment point of the skeleton. Since the movement of the skeleton and its outline attachment points are synchronized, setting attachment points for each skeleton will enable the movement of the outline. We also take the right wing as an example, the motion track of its outline can be shown.



In light of the coverage of each skeleton, the right wing's skin attachment points are divided into three disjoint sets, as shown in Fig. 6. The sets of outline attachment points in the area 1, 2 and 3 are marked as S_1, S_2, S_3. The coordinates of the j attachment point (j = 1,2, ..., mi, i = 1,2,3) in the set S_i are marked as S_1, S_2, S_3, and the mathematical relationship between them is similar to the relationship between skeleton key point A_i and A_i', it can be described by the following formula:

$$\tilde{x}_{ij} = \prod_{\tau=1}^{i} Z_\tau (x_{ij} - A_{i-1}) + \sum_{k=1}^{i-1} \prod_{\tau=1}^{k} Z_\tau (A_k - A_{k-1}) + x_0 \qquad (4)$$

By implementing this method to the body part and the left wing, it is able to obtain one motion trajectory image of this dragon. And since then, we have accomplished the investigation and modeling of non-rigid motion of irregular shape in the two-dimensional plane.

1.3.4 the 3D motion model

After the investigation of 2-dimansionalmotion, we further extend the movement of this western dragon into three-dimensional space. Considering the dragon image is relatively complicated, we split the dragon into body, left wing, right wing and tail, and define the plane where the dragon is located initially as the yoz plane, as shown in Figure 8. At the same time we assume that the body of the dragon still keeps the same yoz plane, the movement of its wings can be defined as rotational movements with Z as their axis. This 3-mimentinal movement can make the air show to be more vivid.

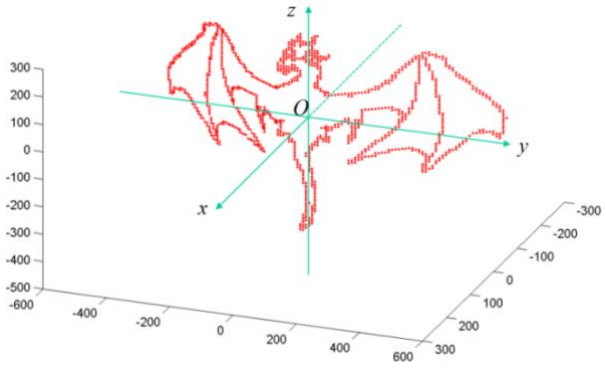


Fig 7. dragon in txhree-dimensional space diagram

In the 3D motion model, we firstly need to convert the 2-dimensional coordinates of the outline points into 3-dimensional coordinates. Because the initial plane of the dragon is yoz, thus 2D to 3D conversion can be achieved by the formula of:

$$\begin{aligned} R^2 &\rightarrow R^3 \\ (x, y) &\rightarrow (0, x, y) \end{aligned} \tag{5}$$

Assuming that a random point $P(x, y, z)$ on the wings is rotated by θ degrees around z-axes and the coordinate is $\tilde{P}(\tilde{x}, \tilde{y}, \tilde{z})$, then the relationship between them can be expressed as

$$\begin{pmatrix} \tilde{x} \\ \tilde{y} \\ \tilde{z} \end{pmatrix} = \begin{pmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} x \\ y \\ z \end{pmatrix} \tag{6}$$

According to (6), we can calculate the track of the dragon's wings during the movement. The simulation in MATLAB is shown in Fig 8:

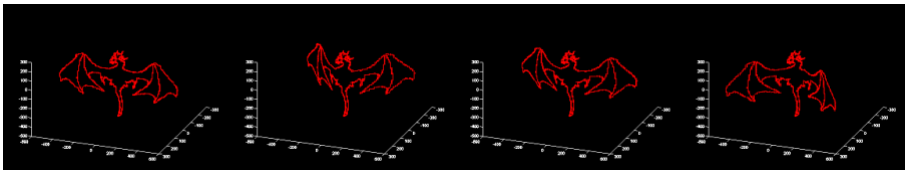


Fig8. Dragon's trajectory dynamic diagram in three-dimensional space motion

1.4 Conclusions

To achieve the model for irregular and non-rigid image, we first scatter the image contours obtained through the pretreatment of samples, then establish a plane coordinate graph and select several key points that are closely related to the graph movement. Largely, the rod device rotation system is a tremendous step to the frame motion model. Second, by triggering those points of attachment to the skin to move simultaneously, we further accomplish the irregularly shaped image in the two-dimensional plane trajectory. Third, applying the three-dimensional matrix converter, we calculate the motion trajectory after converting the graph to the three-dimension and realize the model of the three-dimensional motion of irregular-shaped and non-rigid graph. The models that are listed above have the universality to any non-rigid and complex figures, creating two-dimensionally and three-dimensionally trajectories. These, the investigated models, massively improve the performance, enabling the air show of the unmanned aerial vehicle (UAV) to be visual striking.

1.5 References

1."Intel® Shooting Star™." Intel, www.intel.com/content/www/us/en/technology-innovation /aerial-technology-light-show.html. Accessed 18 Nov. 2017.
2. Dill, Andreas R., and Martin D. Levine. Non-Rigid Body Motion. Http://graphicsinterface.org/ wp-content/uploads/gi1985-55.pdf ed., Montreal. Quebec, McGill University.
3. Agustin. "How to Plot the Sample Mean in a Scatter Plot?" MathWorks, 4 Aug. 2016, www. mathworks.com/matlabcentral/answers/266667-how-to-plot-the-sample-mean-in-a-scatter-plo t? Accessed 18 Nov. 2017.
4. Driessche, P.van Den, and James Watmough. "Reproduction Numbers and Sub-threshold Endemic Equilibria for Compartmental Models of Disease Transmission." Reproduction Numbers and Sub-threshold Endemic Equilibria for Compartmental Models of Disease Transmission, digital ed., pp. 1-21.
5. Esser, Ernie. "UCI Interdisciplinary Computational and Applied Mathematics Program." Linear Spatial Filtering, edited by SungjinAhn, PDF ed., UCI, 2014. Excerpt originally published in ICAMP, pp. 1-4.
6. Fletcher, Tom, editor. "Spatial Filtering" ["Image Processing Basics"]. Coe.utah.edu, Utah, 31 Jan. 2012, www.coe.utah.edu/~cs4640/slides/ Lecture5.pdf. Accessed 18 Nov. 2017.
7. Finnigan, Tom. "Blending Function." Exploring Blending Function, PDF ed., pp. 39-44.
8. "Function B = Boundaries(BW, Conn, Dir)." Fourier.eng.hmc, 9 Mar. 2015, fourier.eng.hmc. edu/e161/dipum/boundaries.m. Accessed 18 Nov. 2017.
9. Bultheel, Adhemar, and Erik Hendriksen. "Gonzales's Boundaries Function." Orthogonal Rational Functions, 4th ed., Cambridge, Cambridge University, 2007, pp. 155-72.
10. "Function B = Bsubsamp(A, Conn, Dir)." Fourier.eng.hmc, 9 Mar. 2015, fourier. eng.hmc.edu/e161/dipum/boundaries.m. Accessed 18 Nov. 2017.
11. E., Lagnese J., et al. Splitting of eigenvalues. Boston, Birkhäuser Boston, 2012. 34 vols.
12. J, Ramsay, and Silverman B. W. Visualizing the results. PDF ed., New York, Springer New York, 2006.