A Dataset for *Bombus lantschouensis* Flight Action Analysis

Zhang Yitian
College of Life Sciences
Sichuan University
Chendu, China
zhangyitian@stu.scu.edu.cn

Li Wenjie
Institute of Zoology
Chinese Academy of Sciences
Beijing, China
754328353@qq.com

Fu Xiangxin
College of Life Sciences
Sichuan University
*Chendu, Chin*a
1573987267@qq.com

Huang Zhengzhong
Institute of Zoology
Chinese Academy of Sciences
Beijing, China
huangzz@ioz.ac.cn

Yang Yi
Institute of Zoology
Chinese Academy of Sciences
Beijing, China
yangyi@ioz.ac.cn

Ge Siqin*
Institute of Zoology
Chinese Academy of Sciences
Beijing, China
gesq@ioz.ac.cn

***Abstract*—*Bombus lantschouensis* is a kind of insect which takes flight as the main activity mode, and has strong flight ability. As a social insect, bumblebee is divided into three castes: male, queen and worker. Different castes have different social division and body structure, which may affect their flight. We selected five representative flight actions, and used high-speed cameras to shoot the specific flight actions of different castes of bumblebee, and then extracted the flight data such as Flapping amplitude, wingbeat frequency, flight speed and wing tip trajectory. These data are helpful to research the evolution of insects, the principle of insect flight and the development of insect bionic aircraft.**

Keywords—bumblebee, insect flight, insect bionic aircraft, wingbeat frequency, high-speed camera

I. Introduction

Bombus lantschouensis, belongs to Hymenoptera, Apidae, Bumblebee, which is large in size, long in life, complete wings, strong flight ability, and flight distance of more than 5km. There are three castes of *bombus lantschouensis:* queen, worker and male[1]. Each caste of *Bombus lantschouensis* is responsible for different tasks and jointly runs a family. In order to adapt to the social division of different castes, they have to evolved different body structures. As a result, there are some differences in flight capability among different stages.

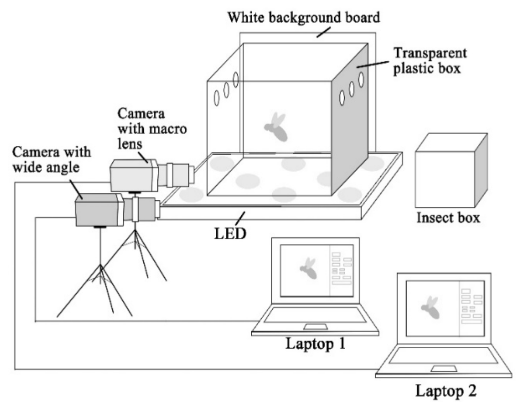
Now we intend to quantify these differences by extracting data from their flight actions. We use the digital method to show the differences of different castes of bumblebee in flight. It is helpful to research the insect flight principle and insect bionic aircraft.

In the experiments, the flight actions of the bumblebee were captured by the high-speed camera v611 produced by VRI (Vision Research Inc.) [2]. Using the software PCC v3.5 [3] of v611 cameras to adjust the video playback speed to survey carefully all the flight actions of bumblebee. The angle between body and flapping plane, flapping frequency and flight speed were extracted from the video, which was used to analyze the body characteristics and living habits of different castes of bumblebees.

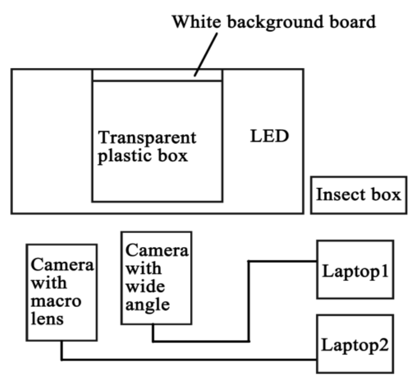
II. Data Collection

A. Data collection preparation

1) Experimental bumblebees: We selected the bumblebees provided by Institute of Apiculture Research in Institute of Apicultural Research, Chinese Academy of Agricultural Sciences. Put them in an insect box with holes on both sides and divide them according to their castes. Cotton balls soaked in sugar water are placed in the insect box and taken back to the laboratory.



(a) Side view



(b) Top view

Fig. 1 Layout of collection environment

2) Data collection environment: Data collection should be placed in a quiet indoor environment to avoid other factors interfering with the behavior of bumblebees. Prepare a transparent plastic box with a length width of 35mm * 35mm * 35mm and place it on the LED. Two camera are set in front of the box to capture the flight actions of bumblebees from the same angle, so as to improve the video shooting

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efficiency. A white background plate is placed on the back of the box facing the camera to make the flight movements easy to distinguish, as shown in Figure 1. One bumblebee was placed each time. After shooting, each bumblebee was soaked in a cell tube filled with 75% alcohol, so as to facilitate the subsequent morphology measurement.

3) Data collection instruments: We used VRI v611 high-speed camera (as shown in Figure 2) to capture bumblebee flight movements. The frame rate is set to 5400 FPS, and the image resolution is 1280 * 720. A flight action of bumblebee was recorded in 0.04-1.00 seconds (about 140-5400 frames). It can clearly reflect the wing flapping and flight trajectory of bumblebee. Figure 3 shows pictures of the bumblebee before and after takeoff.


Fig. 2 Picture of phantom v611


(a) Before takeoff


(b) After takeoff

Fig. 3 Snapshot before and after takeoff

Two high-speed cameras are installed with an ordinary lens and a wide-angle lens, respectively. The advantage of wide-angle lens is that the field of view is relatively wide, and the plastic box can be completely put into the picture, as shown in Fig. 4 (a). Even if the bumblebee flight trajectory is disordered, the wide-angle lens can still shoot the complete trajectory without moving the camera or adjusting the focal length. The disadvantage of this lens is that the resolution is relatively low. Although the resolution is enough to analyze the flight trajectory, the data error will be too large when analyzing the details of bumblebee's wing flapping frame by frame. The advantage of ordinary lens is that the resolution is relatively high, which can clearly record the details of bumblebee wing flapping as shown in Fig. 4 (b). But the disadvantage is that the whole plastic box cannot be captured by one shot. If the bumblebee moves in a large range, it is necessary to move the lens and adjust the focal length. When the bumblebee moves very fast, it is difficult to predict the flight trajectory. Usually, the speed of manually moving the lens and adjusting the focus is too slow, which will cause the video out of focus, and even the target bumblebee completely flies out of the picture. Therefore, the use of wide-angle lens and ordinary lens in turn can effectively improve the shooting efficiency and video quality.


(a) Wide angle shot


(b) ordinary shot

Fig. 4 Pictures taken by wide angle lens and normal lens

When the pause button is pressed, the camera will automatically record the image taken within 2 seconds before the button is pressed. After the images of the camera are transmitted to the computer, they are directly imported into PCC software for editing and transferring. In addition, computer can also control the camera. The operator of the camera and computer can observe the bumblebee flight at the same time and control the camera to record the flight fragments, so as to improve the work efficiency.

B. Data collection process

Turn on the fill light, debug the camera, and run PCC software. Remove the bumblebee from the insect box and put it into the acrylic box. When the bumblebee is in the target flight state, adjust the focal length of the camera so that the two cameras can take pictures alternately and receive them in the computer.

In the initial stage, bumblebee is energetic and has a long time to hover and fly forward, so we mainly focus on capturing the video of forward flight and hovering.

C. Data collection results

A total of 7 males, 9 workers, 9 after-mating queens and 8 before-mating queens were collected. A total of 249 bumblebee flight video was collected, which was about 61.9 seconds, and 237192 frames.

III. DATA EXTRACTION

A. Definition of flight actions

We define five kinds of flight actions for data extraction and research from the captured video. The five kinds of flight actions are: taking off, ascending, forward flight, hovering and turning round. The definition of these actions is as follows:

- Taking off: The forefoot of bumblebee lift off the ground and fly upward.
- Ascending: The bumblebee flies upward, and the angle between the direction of body movement and horizon is greater than 30 degrees.
- Forward flight: The bumblebee flies toward one direction without stopping.
- Hovering: The bumblebee stays in the air, flapping its wings but does not move, or the motion distance is very short, and the body is shaking slightly.
- Turning round: The bumblebee flies while the direction of its movement changes considerably.

B. Attributes extracted from data

The following attributes will be extracted from the captured video:

- Flapping amplitude: from the side view, the straight-line distance between the leftmost point of the forewing flapping and the rightmost point of the forewing flapping is the wing flapping amplitude in a wing flapping cycle. The accuracy of the data is improved by calculating the average values after manipulating several times. However, due to the variations of wing flapping amplitude during taking off, the average value is not taken during taking off.
- The angle between the body line and the flapping line: the body line is the line between the leftmost point and the rightmost of the forewing flapping in a flapping cycle. The flapping line is the line between the farthest point of the head and the farthest point of the tail of the bumblebee. The accuracy of the data is improved by calculating the average value by manipulating several times. However, due to the variation of wing flapping amplitude during taking off, the average value is not taken during taking off.
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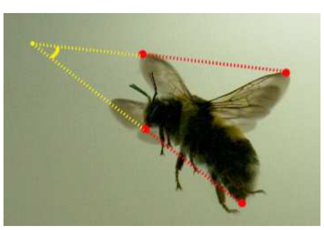

Fig.5 The angle between the body line and the flapping line

- Wingbeat frequency: the wingbeat number in one second. The accuracy of the data is improved by calculating the average value by manipulating several times. However, due to the variation of wing flutter amplitude during taking off, the average value is not taken during taking off.
- Flight speed: the flight distance divided by the flight time. The flight speed is not collected and analyzed during taking off and hovering.
- Wing tip trajectory: In our experiments, it is found that the high-speed camera can capture a complete flapping period with 17-23 frames. Trace the wing tips in each picture, measure the coordinates of the obtained tips, and put together the wing tip coordinates of 17-23 frames, which is the wing tip trajectory.

C. Scale calibration

Because PCC cannot calculate the depth of field, it is necessary to calibrate the scale before extracting data. In order to minimize the errors, we plan to take the shape values of the existing bumblebee specimens, and take the average value as the calibration data. Therefore, we have to complete the measurement of shape before the video data collection.

Take out a specimen from the centrifuge tube and put it on the filter paper to dry the ethanol for standby. The foam board with coordinate paper was placed under the dissecting microscope, adjusted the focal length of the dissecting microscope, transferred the bumblebee sample from the filter paper to the foam board with insect needle and tweezers, and measured the bumblebee body length, The distance between the bottom of the wings, wing length and wing width. The measurement results are accurate to three places after the dot, in centimeters.

Then we can manipulate the scale calibration according the following steps. Select "calibration" in the "measurement" menu item in PCC software, click "calibrate", mark the starting point and midpoint of the reference material, and input its actual length to complete the scale calibration. Although the depth changes during the flight, there is no need to recalibrate because of the small-scale change.

D. Extraction method

The front side video is very helpful to data extraction. figure 6 (a) shows the picture taken from the front side, and the wings almost overlap. We call the video similar to figure 6(a) the front side video. As shown in Fig. 6 (b) and Fig.6 (c), video are shot from the front or back, or any other angles, the two wings do not overlap. We call these video “ Other angle video”.

(a) (b) (c)

Fig.6 Pictures taken from different angles

- Flapping amplitude ：We need select the front side video to measure the wing flapping amplitude. We load the video into PCC software, take the point at the initial highest point of the flapping cycle, then play the video to take the highest point at the end of the flapping cycle. The software can automatically calculate the length (play > measurements > instant measurement, check active, select "distance & Angel & speed: 2 points", select the starting point, press the play key, and then select the end point. You can see the results in the "result" section.)

- The angle between the body line and the flapping line：We also need select the front side video to measure the angle between the body line and the flapping line. We load the video into PCC software, manipulate play > measurements > instant measurement, check active, select "angel & angular speed: 4". Select the highest point of the wing at the beginning of a wing flapping cycle, press the play key, and then select the highest point of the wing at the end of the flapping cycle. A bright line representing the flapping plane appears, and then select the line of the body of the bumblebee (select the farthest point in the head and the farthest point in the tail). The result is shown in the "result" section.
- Wingbeat frequency：We manually count the total times of the wingbeat in the video. Wingbeat frequency is the total times divided by the duration of the video.
- Flight speed：Select "distance & Angel & speed: 2 points", select the coordinates at the starting point, press the play key, and then select the coordinates of the end point. You can see the result in the "result" section, that is, the flight speed.
- Wing tip trajectory：All the images of one flapping cycle are exported from PCC frame by frame, and dragged into Adobe Photoshop® (hereinafter referred to as "PS"). The wing tips in each image are traced and connected to form an "8" shape, which is exported as a image, as shown in Figure 7.

Fig. 7 The flight path of bumblebee

Import the image into Adobe Illustrator® (hereinafter referred to as "Ai"), select the measurement tool in the Ai toolbar. The measurement tool also provides the coordinates of the location of the mouse cursor, which can be used to obtain the coordinates of each wing tip. Firstly, trace the track and wing base in Ai, convert the raster image processed in PS into vector image in Ai, then record the coordinates of wing base and each wing tip. The scale of the coordinates needs to be converted from pixels to cm by the equation (1).

$$C_a = C_p * Lw_a / Lw_p \quad (1)$$

C_a is the actual coordinates in cm. C_p is the coordinates in pixel. Lw_a is the wing length of the bumblebee in cm. Lw_p is the wing length in pixel.

Lastly, we manually fill the coordinates of wing base and wing tips into the table as the wing tip trajectory of the bumblebee.

E. Data format

The measurement results of each bumblebee specimen fill a table as shown in Fig. 8, and the tables of all bumblebees form a dataset file, which is placed in the same directory as the video file.

Video Number	Castes	Flight status	Video shooting angle	Extract content	Specific extraction content	Unit
	queen(after mating), queen(before mating), worker, male	Taking off, Ascending, forward flight, hovering, turning round	Front Side video	Shape data	The body length, wing base spacing, wing length, forewing width	cm
				Flight speed	Displacement length	cm
					Speed	cm/s
				Flapping frequency	Number of flapping	times
					Flapping frequency	times/sec
				Angle between body line and flapping line	The angle on the points of equal division	degrees
					Mean value of angle	degrees
				Wingbeat amplitude	The amplitude of wingbeat at the point of average division	cm
					Mean value of amplitude	cm
				Wing tip trajectory	Coordinates of wing tips in a period of wingbeat	（x, y）
					Coordinates of wing base	（x, y）
					Scale	
				Video duration		s
			Other angle video	Flight Speed	Displacement length	cm
					Speed	cm/s
				Flapping frequency	Number of flapping	times
					Flapping frequency	times/sec
				Video duration		s

Fig.8 Unified data format

IV. Results and Discuss

A. Dataset statistics

Fig.9 shows the specimen distribution of different castes. There are 9 workers, 7 males, 9 after-mating queens and 8 before mating queens.

Fig. 10 compares the number of effective videos of each caste. There are 49 videos for male, 80 videos for worker, 45 videos for after-mating queen and 75 videos for before-mating queen.

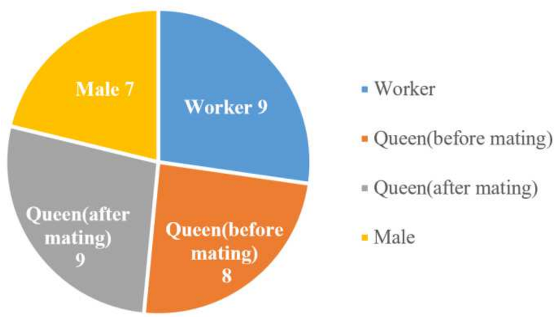

Fig. 9 Statistical pie chart of bumblebee specimens of different castes

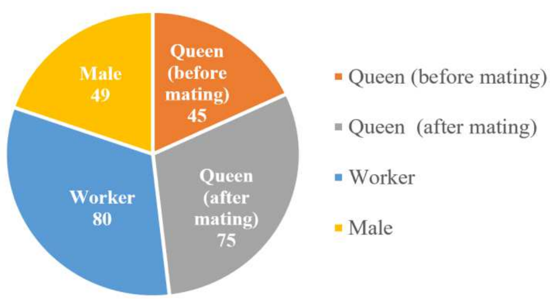

Fig. 10 Effective video pie chart of bumblebee

Fig. 11 shows the effective video statistics of different flight states for each caste.

B. Further work

Compared with the related research [4], we need supplement more effective video for this data set, especially supplement the effective video of male and worker bumblebee hovering.

In addition, it is necessary to process and compare the flight data of different castes to obtain the differences among different flight actions. Combined with the social characteristics, external shape and internal structure characteristics of bumblebee, as well as the physical force analysis during flight, the data differences need be explained.

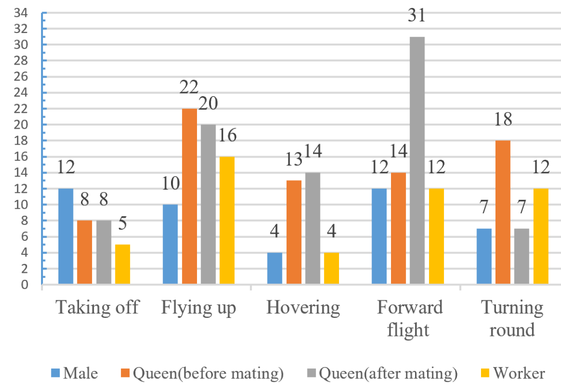

Fig. 11 Effective video statistics of different flight actions for each caste

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