Fast adaptive jump of the cricket *Gryllus bimaculatus*

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1 Motivation of AMAM

Fast movement is one of the crucial traits for animals to survive potential threats. Predator, for example, moves fast to hunt prey, on the other prey shows quick escape from the predator.

Understanding the mechanisms underlying fast adaptive movement must be a common issue between biologists and robotics scientists. Biologists have investigated how animals evolved the design principle for generating quick movements. On the other hand, robotics scientists have been interested in the design and control law for their robots to behave like animals. Cricket has been used as a model animal to investigate many kinds of behaviors, for example, escape behavior [1-3], locomotion [4], aggressive behavior [5,6], learning and memory [7] and more. Therefore, cricket has been provided us good model system to investigate the mechanism underlying adaptive behavior.

We here focus on cricket jump. Cricket kicks the ground to jump using walking legs. Hindleg function to bounce off the body. The movement of the hindlegs during the escape jump has been investigated in cricket. We here add other jump motions of the cricket in this study. That is an offensive jump during the fighting between male crickets. During the offensive jump, cricket brings up the opponent to bounce away. The movement of the offensive jump is highly adaptive because the target is always moving. Therefore, understanding of the mechanism to generate offensive jumps in cricket must contribute to designing robots that can move, for example, on the wasteland.

Figure 1: Cricket Fighting

2 Materials and Methods

2.1 Animals

The Crickets *Gryllus bimaculatus* (De Geer) were reared in plastic cases (45cm × 30 cm × 20 cm) on a 12h: 12h light and dark cycle at 27 ± 2ºC. They were fed a diet of insect food pellets (Oriental Yeast Co., Tokyo, Japan), chopped carrots and water ad libitum. Adult males that were 2-3 weeks from the final molt were used for behavior experiments.

2.2 Behavior experiments

Crickets express jumping behavior when they detect air-displacement as potential threat. The cricket also express jumping when it attacks the rival cricket during fighting. To examine the motion differences between escape jump and attacking, we performed behavior experiments. Test cricket was kept isolated in 100 ml grass beaker for 1 week to reduce the effect of previous experiences. The crickets were places in an experimental arena made from acrylic. To introduce escape behavior, the cricket cercus was stimulated by air puff. On the other hand, to introduce attacking jump, a pair of males were placed in the same arena (Fig. 1). Each jump was recorded by pair of high-speed cams HAS-U2 (DITECT Co., Tokyo, Japan.) The recorded movements of the crickets were tracked, and kinematic analysis was performed using free softwares DeepLabCut [8, 9] and Kinovea.

3 Results and Discussion

3.1 Motion Analysis of Escape Jump

The cricket detects air movements using sensory hairs attached on the cercus [1-3]. Applying week air stimulation elicited avoidance walk to leave from the stimulus source. Stronger air puff elicited escape jump in the cricket. Jump angle and distance seemed to depend on the strength of the air stimulus. To gain understanding of the escape behavior of the cricket, we here investigated detail motion during the escape jump. We found that the jump trajectory has some variety with points of takeoff angle and height. In case of fast and powerful escape jump, the cricket flexed fully femur-tibia joint of the hindlegs prior to kick the ground (Fig. 2b). This result accords with previous report [2]. On the other hand, in case of short-distance jump, crickets did not fully flex the leg joint (Fig. 2a). The cricket would adaptively express the escape jump dependent on the situation.

3.2 Motion Analysis of Attacking Jump

The jump observed in fighting behavior seemed to different type of jumping. To gain an understanding of the control principle of the jump, we compared the difference between the escape jump and the attacking jump. A pair of isolated crickets suddenly start fighting when they are placed in the same place. The fighting usually starts from antennae fencing and then

escalates to violent attacks. The fight continued until one of them retreated from the opponent. Before retreating, the loser was bounced off by the opponent. To bounce the opponent, the future-winner cricket showed a powerful attacking jump (Fig. 3). The attacking jumps seemed highly adaptive since the cricket would be required to jump at the exact position. Otherwise, it would be difficult to bounce off the opponent.

Compared to the escape jump, attacking jump seemed to be less variation. The cricket placed its mandible under the head of the opponent and then expressed powerful jump. The motion tracking of the hind leg suggested to us that the cricket prepare to keep a particular poster before jumping. Since the sequence of the attacking jump seemed to be like formulaic. This indicates the control the attacking jump well-coordinated, since the condition of the ground is always changing during the fight.

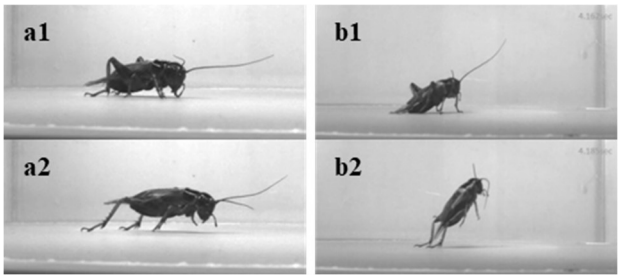

Figure 2: Snap shots of escape jump (a) short-distance jump (b) long-distance jump

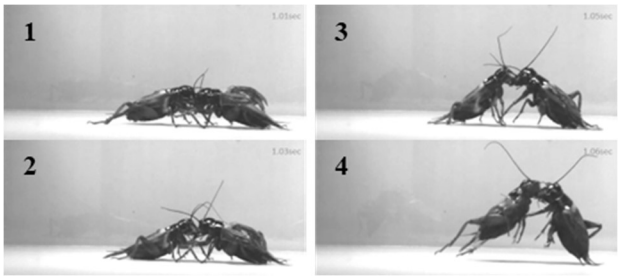

Figure 3: Snap shots of attacking jump

4. Conclusion

The cricket shows 2 different types of jumping. One is escape jump and the other is attacking jump. When escaping, cricket starts jumping from variable postures. Thus, the crickets show shorts or long-distance jumps. This could function to retreat from potential threat quickly. In case of attacking jump, the jump seemed like formulaic. The aim of the jump is to bounce off the opponent. Therefore, the cricket could be required to keep better posture. Our study would be the groundwork to investigate adaptive movements of the animals under changing environment. The cricket supplies us better experimental system to study physical and physiological mechanisms underlying adaptive movements.

5. Acknowledgements

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