Miniature Jumping Robot With Consecutive Jumping Ability

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Unmanned ground vehicles are mostly wheeled, tracked, or legged. These locomotion mechanisms have a limited ability to traverse rough terrain and obstacles that are higher than the robot's center of mass. In order to improve the mobility of small robots it is necessary to expand the variety of their motion gaits. Jumping is one of nature's solutions to the challenge of mobility in difficult terrain. A miniature jumping robot, inspired by the desert locust was developed and presented in [1]. The basic mechanism is similar to that of the semilunar process in the hind legs of the locust, and is based on the cocking of a torsional spring by wrapping a tendon-like wire around the shaft of a miniature motor. However, this robot, while demonstrating impressive autonomous jumps, is uncontrolled while airborne and does not land gently. Rather, it simply falls from its peek height of over $3m$, and ends up in an arbitrary orientation. This means that the robot cannot perform a series of planned jumps to get from one point to another due to two separate issues, both related to the arbitrary landing orientation. First, in order to perform a second jump, the robot needs to be ”feet down”, but there is no guarantee that it will land feet down. Second, the robot can only jump in the direction it is pointing at, which, again, is arbitrary due to the nature of the uncontrolled flight and fall of the robot. One approach to control the landing of the robot was suggested in [2]. The idea was to spread wings when the robot reaches the apex of its trajectory, thus slowing down and stabilizing the descent of the robot. Results have shown that this approach pretty much helped solving the problem of landing feet down, but control of the orientation towards a second jump was difficult. In addition, all corrections are limited to the airborne portion of the jump and no corrections to orientation could be made when on the ground. The locust-inspired robot is shown in Fig. 1 above a real locust and next to its winged version.

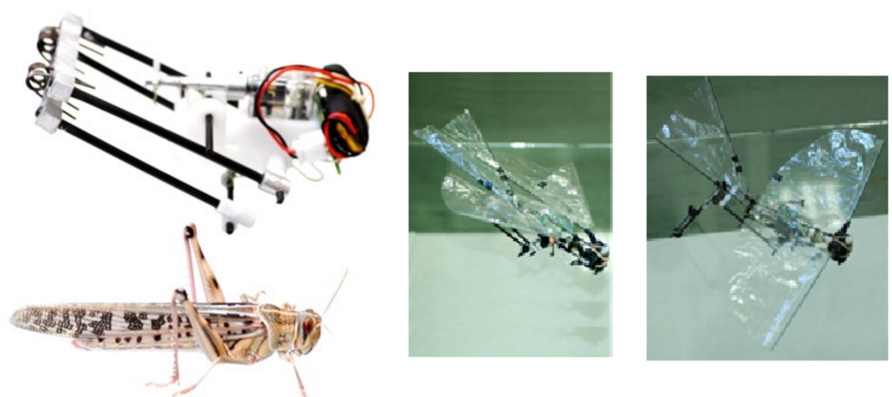

Fig. 1: Left: Locust inspired robot above a real locust. Right: Winged version

To solve this problem a new approach is suggested. The idea is to reorient the robot after landing, prior to the next jump. This is done using a propeller-looking extension of the motor's shaft as depicted in Fig. 2. The propeller is mounted on the shaft via a unidirectional bearing, allowing free rotation to one direction, but preventing rotation in the other direction. The length of the extension is determined such that the propeller does not interfere with the loading and releasing of the springs for the jump. Once the springs are loaded and locked, turning the motor operates the propeller-looking mechanism. When the propeller is rotated, the end of the propeller hits the ground. The reaction force from the ground creates a moment, trying to rotate the body of the robot. Since the feet-down orientation of the robot is the most stable (widest footprint), the robot tends to stay on its feet once it gets there. To set the heading, the body rotates about both the motor axis and about the axis connecting the end of the

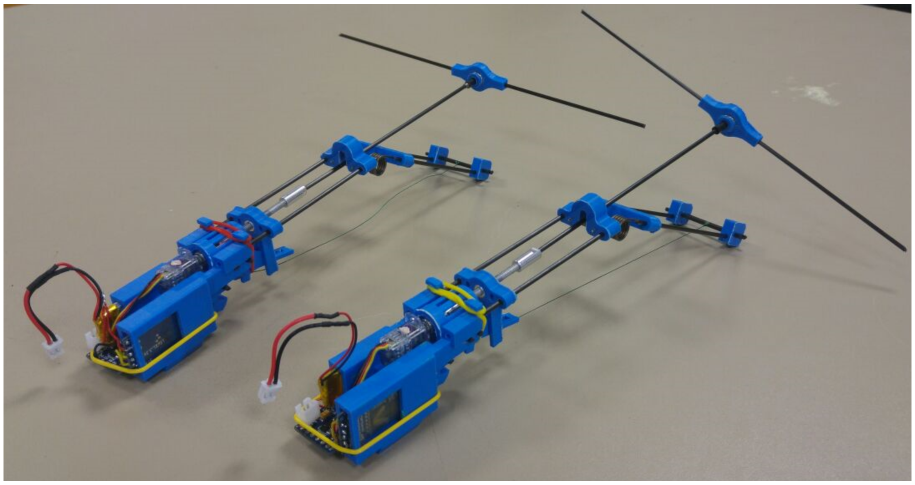

Fig. 2: Jumping robots modified with propeller looking extension allowing them to turn

propeller and its hind feet. As a result, the robot both flips and changes its heading. This allows both controlling the heading of the robot for the next jump, and turning the robot on its feet. All this is performed autonomously using an off-the-shelf integrated measurement unit (IMU) consisting of three accelerometers, three gyroscopes and a magnetometer. The algorithm has the following steps:

1. Detect the landing utilizing the accelerometer readings.
2. Load the springs until the locking mechanism connects.
3. Start rotating the propeller in short bursts while measuring orientation.
4. When appropriate heading (within a margin) detected and the robot is on its feet, release the springs.

The robot utilizes a single DC motor for all operations which include loading the springs, locking them, releasing the springs for the jump, flipping the robot on its feet and adjusting the heading. The robot was constructed and is able to demonstrate consecutive directed jumps and jumps from point to point autonomously. Analysis, results and videos of the robots' performance will be presented.

References

[1] V. Zaitsev, O. Gvirsman, U. Ben-Hanan, A. Weiss, A. Ayali, and G. Kosa, "A locust-inspired miniature jumping robot," *Bioinspiration & Biomimetics*, vol. 10, no. 6, p. 066012, 2015.

[2] A. Beck, V. Zaitsev, U. Ben-Hanan, G. Kosa, A. Ayali, and A. Weiss, "Jump stabilization and landing control by wing-spreading of a locust-inspired jumper," *Bioinspiration & Biomimetics*, vol. 12, no. 6, p. 066006, 2017.