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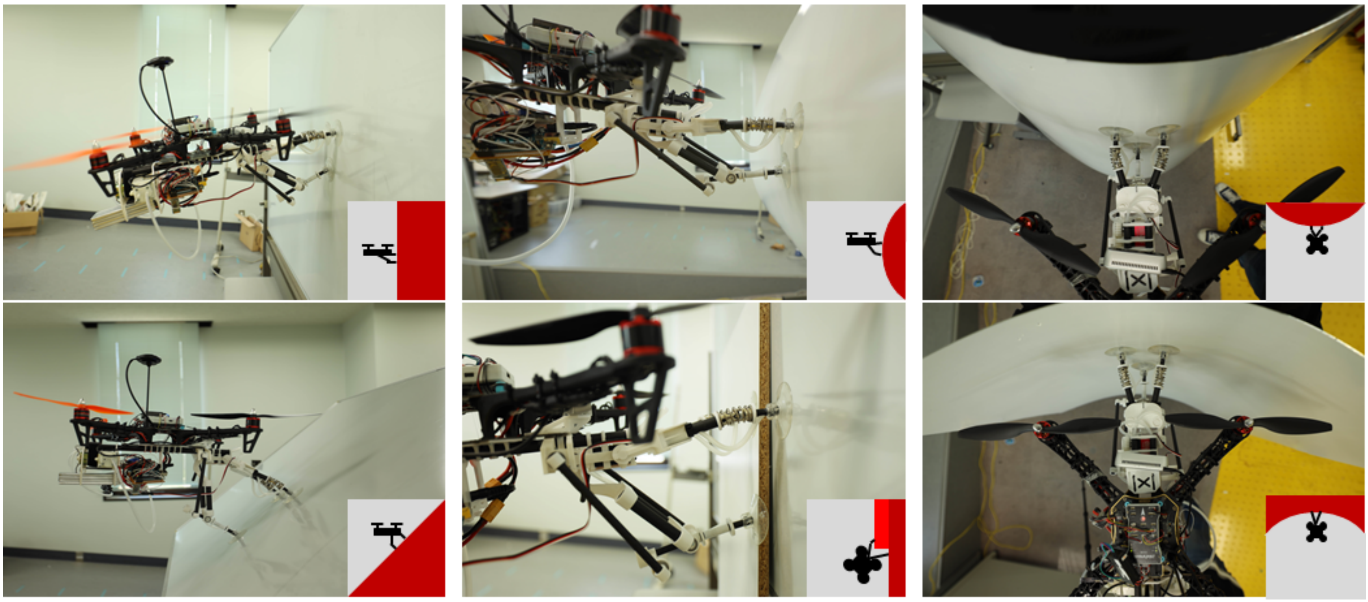
Enabling Landings on Irregular Surfaces for Unmanned Aerial Vehicles via a Novel Robotic Landing Gear

Tsung Hsuan Huang, Armagan Elibol, and Nak Young Chong



Landing on arbitrarily shaped surfaces. The landing gear connects to a variety of surfaces through passive universal joints.

***Abstract*— Over the last decade, unmanned aerial vehicles (UAVs) have been performing a variety of tasks (*e.g.,* inspection, data gathering and similar others) in environments that are considered hostile and dangerous for humans. Specifically, wall-climbing UAVs have been proposed for inspection, collecting data with contact-type sensors. Along the lines, researchers are working on designing UAVs that are capable of landing or touching the surface to be inspected. In this paper, we present a lightweight robotic landing gear, consisting of 3 robotic legs, to enable UAVs to land on almost any types of irregular surfaces. We present experimental results under different scenarios in our laboratory settings.**

I. Introduction

Recently, the capabilities of UAVs have been extended to aerial photography, entertainment, and similar others thanks to the technological improvements in payload capacity, endurance, flight stability, and the decline in price. There have been increasing demands from various fields that are capable of cooperating with their surroundings (*e.g.*, Inspection [1] and agriculture [2]). Different designs [3], [4] have been developed accordingly to the nature and needs of tasks.

Most of the existing UAV designs could only allow them to land on flat surfaces [5], which limits the applicability of UAVs. Some of them can only connect with vertical surfaces [1] and others can only operate on horizontal surfaces [6]. However, many non-planar surfaces also have to be inspected in real life. Therefore, there has been an increasing interest in designing a UAV capable of landing on uneven and/or non-planar surfaces. This would allow them to collect data from such surfaces for inspection and monitoring as well as similar other tasks. In this paper, a new robotic landing gear design is presented using some passive structure with a single motor to connect with any shape of the surface.

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II. Robotic Landing Gear Design

The proposed landing gear with a mechanical structure is less than 900g and designed to use only one servo motor with passive mechanical structures keeping its weight low. This design is composed of 3 robotic legs. While two frontal legs are fixed in terms of length, the back leg is able to change its angle and length simultaneously thanks to the linkage method of multiple rods. Another advantage of using multiple rods is that it provides ability to make the front and the back leg have different angle changes, thus it can land on non-planar surfaces. The frontal part of the robotic legs consists of a vacuum cup, a set of universal joints, a compression spring, and a vacuum tube. The vacuum cup and vacuum tube is in charge of the connecting to the surface inspected. The universal joints and compression spring can guide the vacuum cup to adapt to different shapes of landing surfaces.

When the UAV needs to leave the surface, the vacuum system needs to be decompressed to release the vacuum power so that the UAV can take off smoothly. For this reason, we design a passive decompression device according to the attitude of the UAV, the surface contact process, and a pressure relief hole (as shown in Fig. 1). This hole is based on different load weights of the vacuum cup adsorbed on the vertical wall. The position of the suction area in the vacuum cup will be different according to the load weights of the vacuum cup.

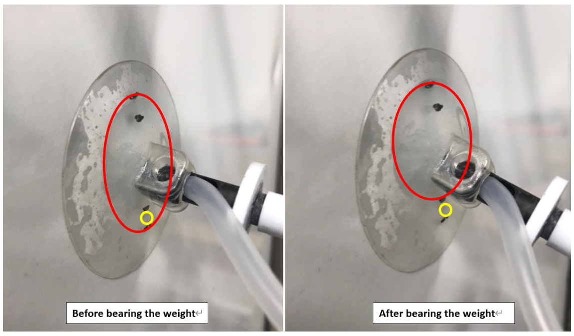

Fig. 1. When the robotic leg begins to bear weight, the section area in the vacuum cup will move upward, thereby closing the pressure relief hole. When the multicopter increases its power, the section area in the vacuum cup will return to the center, and the pressure relief hole will be opened to destroy the vacuum environment.

We also design the counterweight, which is composed of the vacuum motor and single-board computer. The weight reduction and the center of gravity change adjustment become particularly important. The counterweight control part can manually move horizontally on the landing gear before taking off. To ensure that the landing gear is in any position, the overall center of gravity will not change drastically.

III. Experiments

In experiments, we use 6 different types of surfaces, including vertical surface, 45° angled surface, discontinuous surface with height differences, and 3 types of the curved surface. When the landing area is flat, we observed that the designed landing gear can connect quickly and firmly to the target surface. When the surface has high curvature, although it will not affect the robotic legs' adsorption capacity, it takes more time to connect the robotic leg firmly to the surface.

We also tested the functional adaptation of the universal joint, which is installed at the frontal part of the robotic legs. When the soft rubber part of the vacuum cup touches the landing surface, the friction between the rubber and the surface guides the universal joint, keeping the vacuum cup perpendicular to the surface as shown in Fig. 2. This endows the robotic legs with the capability of connecting to irregular surfaces. During the experiments, we observed that the design of the pressure relief hole has provided a good performance on both the planar and curved surfaces in terms of easiness of detaching. Due to the pressure relief holes, vacuum cups cannot attach to the surface directly and can slide on the surface. This provides flexibility to land on irregular surfaces since it can correct its position when the UAV touches the surface.

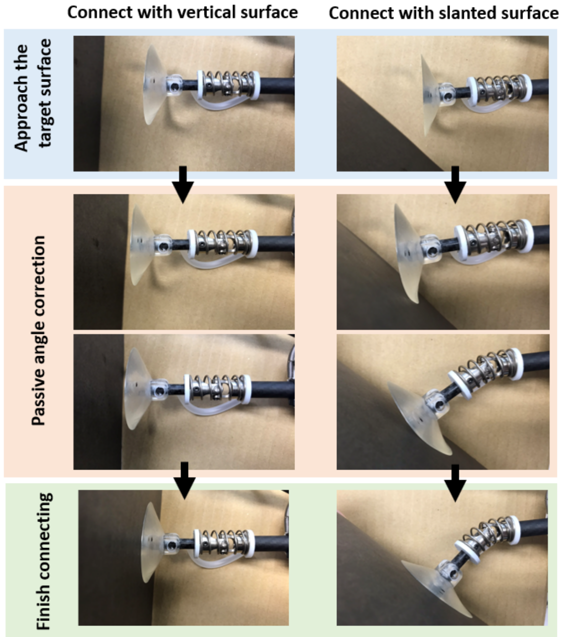

Fig. 2. According to different angles of the surface, the robotic legs work passively, automatically adjusting the vacuum cup's angle when contacting the surface.

IV. Conclusions and Future Directions

In this work, the proposed robotic landing gear allowed the UAV to land on irregular surfaces. A passive angle adjustment method was adopted based on the mechanical structure to effectively reduce weight and power consumption. It was demonstrated through laboratory experiments that the landing gear can be easily connected to various types of flat and curved surfaces.

On the other hand, we have found that the proposed landing gear cannot effectively land on stepped planes having discontinuous surface elevation patterns, and other complex terrains. Future directions of the research are aimed at solving the aforementioned issue by changing the design of the back robotic leg.

References

[1] W. Myeong, S. Jung, B. Yu, T. Chris, S. Song, and H. Myung, "Development of wall-climbing unmanned aerial vehicle system for micro-inspection of bridges," in *Proc. IEEE International Conference on Robotics and Automation*. IEEE, 2019.

[2] M. Jarman, J. Vesey, and P. Febvre, "Unmanned aerial vehicles (uavs) for uk agriculture: Creating an invisible precision farming technology," *White Paper, July*, 2016.

[3] P. Ratsamee, P. Kriengkomol, T. Arai, K. Kamiyama, Y. Mae, K. Kiyokawa, T. Mashita, Y. Uranishi, and H. Takemura, "A hybrid flying and walking robot for steel bridge inspection," in *Proc. IEEE International Symposium on Safety, Security, and Rescue Robotics*. IEEE, 2016, pp. 62–67.

[4] A. Jimenez-Cano, G. Heredia, and A. Ollero, "Aerial manipulator with a compliant arm for bridge inspection," in *Proc. International Conference on Unmanned Aircraft Systems*. IEEE, 2017, pp. 1217–1222.

[5] W. C. Myeong, K. Y. Jung, S. W. Jung, Y. Jung, and H. Myung, "Development of a drone-type wall-sticking and climbing robot," in *Proc. International Conference on Ubiquitous Robots and Ambient Intelligence*. IEEE, 2015, pp. 386–389.

[6] K. Ito and Y. Fukumori, "Autonomous control of a snake-like robot utilizing passive mechanism," in *Proc. IEEE International Conference on Robotics and Automation*. IEEE, 2006, pp. 381–386.