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A Design of Bionic Gripper to Enhance the Persistence of Wild Life Monitoring Performed by Drone

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Abstract

This study presented a bionic gripper which is designed for drones, in order to enhance the reliability and stability and the perching abilities of drone landing in complex landing environments, such as tree branches in forests[1]. The gripper utilized a self-locking mechanism that minimizes the energy consumption at the same time while ensuring the secure gripping on irregular surfaces. With the use of CAD tools including SolidWorks and Fusion 360, the gripper was designed, simulated, and optimized for a lightweight performance. This system is designed particularly to benefit wildlife monitoring by drones, which is especially for endangered species like the crested ibis. This system allows a prolonged observation with minimal disturbance inside animal habitats, which offers a non-invasive approach to ecological researches.

In recent day, drones have become an essential tool in environmental observation and wildlife animal monitoring. It is undeniable that the effectiveness of this tool is often limited by challenges in landing and energy efficiency, particularly in dense forest environments. To address this potential problems, this study proposes a bionic gripper which is inspired by bird talons [2] for enhancing drone landing capabilities, enabling a stable landing on complex environments for example tree branches. The gripper features a self-locking mechanism, which highly reduces the energy consumption while maintaining a stable and reliable holding. Using SolidWorks and Fusion 360, the gripper was designed and stimulated for a lightweight and adaptive performance. A key application of this technology is in the conservation for endangered species such as crested-ibis. This system is allowing drones to conduct long-term, low-disturbance observation, which not only extends the operation time but also minimizes the interference from noises, that contributes to a more sustainable and effective wildlife research as well as environmental monitoring.

Keywords: bionic gripper, drone landing, wildlife monitoring, self-locking mechanism, biomimicry, energy efficiency, crested ibis conservation, forest ecosystem, CAD Optimization, non-invasive observation

1. Introduction

In recent years, the use of drones in environmental observation and wildlife research is growing rapidly, providing scientists with a new perspective on ecosystems and the behaviors of species in their own natural habitats. However, one of the key challenges of this technology, in deploying drones for wildlife monitoring, particularly in dense forest environments, is managing safe and efficient landings. Traditional drone designs are lack of the adaptability in handling such conditions, which limits both the flight time and reliability in observation.

In order to address these limitations, the technology of this project is proposing the use of bionic grippers to enhance the capability of drone's landing in complex environments. Inspired by the adaptive gripping mechanisms found in bird talons and other natural models, these bionic grippers would allow drones to land securely on uneven surfaces like branches, improving stability and minimizing energy consumption. By offering the ability to perch, rather than hover continuously, drones can conserve battery life, thus extending observation periods. This innovation not only enables drones to better mimic the non-invasive qualities of bird perching but also reduces the disturbance to the natural environment, which is essential for studying wildlife, particularly birds, in their undisturbed habitats.

2. Designing

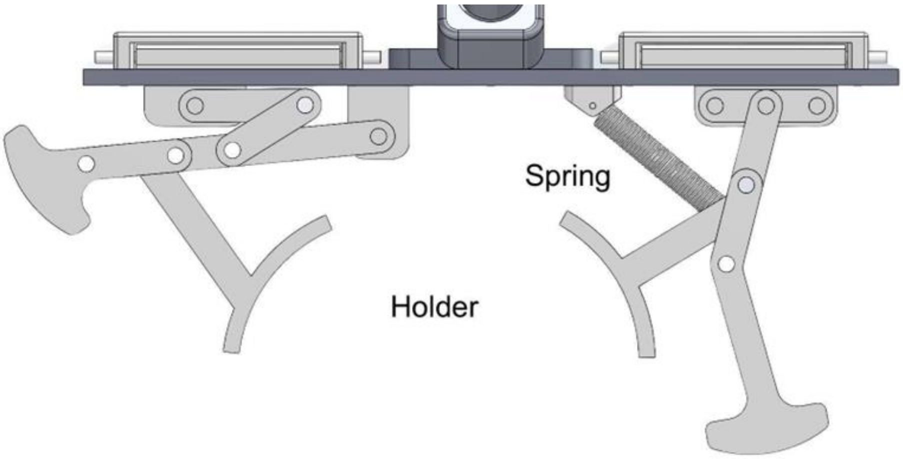

Figure 1.

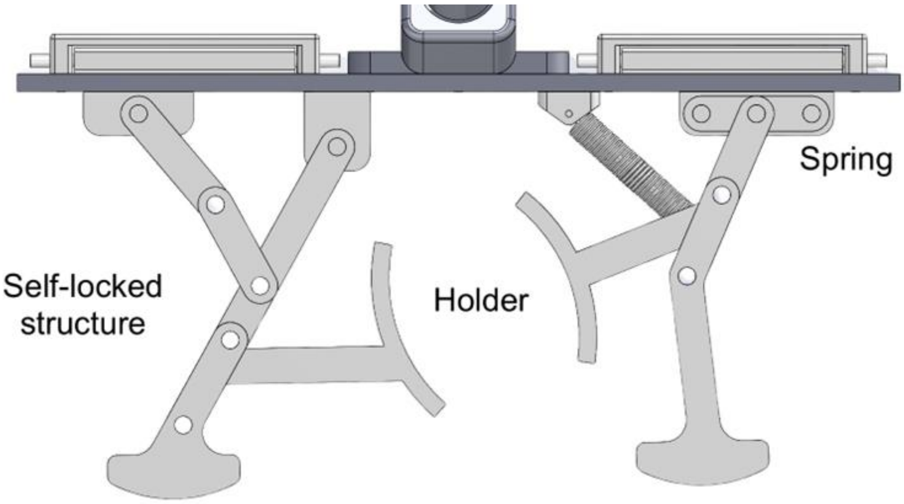

Figure 2.

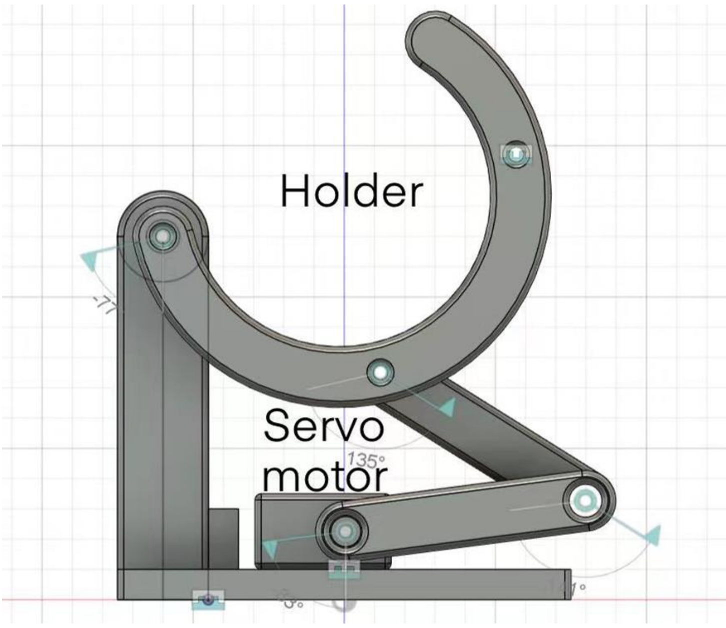

Figure 3.

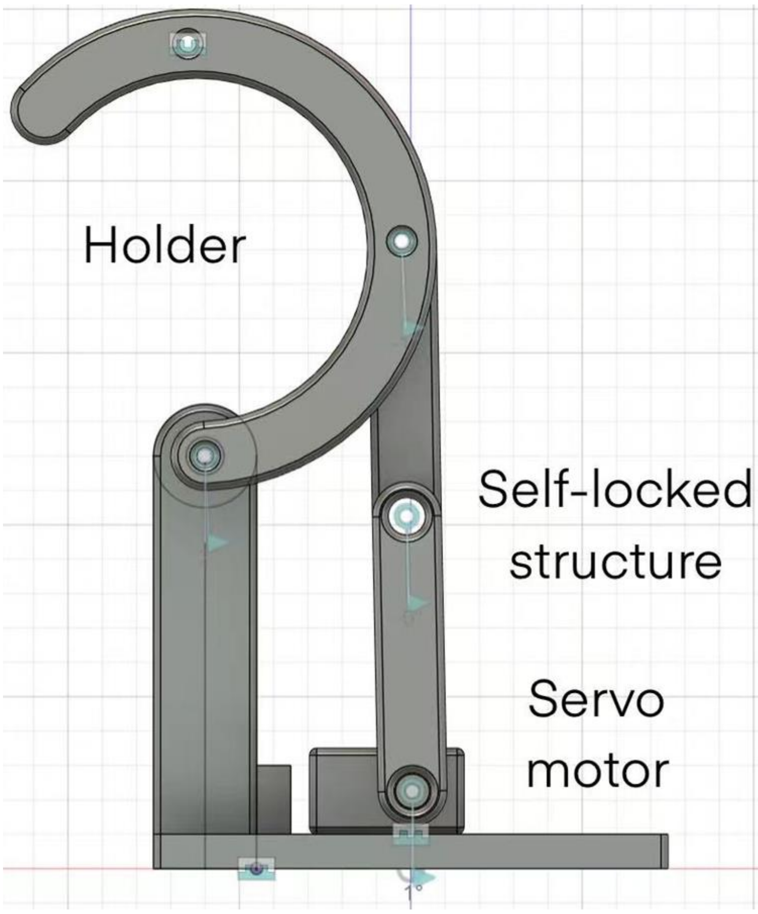

Figure 4.

Figure 5.

There are five pictures showing the design of the gripper. The bionic grippers presented here feature a mechanical structure engineered to enable stable landing on complex surfaces, such as tree branches, with utilizing a self-locking mechanism. The design was created using CAD tools including SolidWorks and Fusion 360.

The Figure 1. and Figure 2. display the original design of the gripper, which is intended to be installed beneath the drone body. This design is inspired by the common landing style of birds in the natural world. However, this design has a drawback that are difficult to be addressed, where it takes up a large size, and are not reliable and stable enough while working in real world.

The Figure 3. and Figure 4. along with the real-world photograph in the fifth picture, are showing the improved version. This updated structure is inspired by the torpor style of hummingbirds, which hang inversely from tree branches while resting and preparing for attack. A real-world prototype has been developed to test the reliability and stability of this structure.

3. Structure of the Gripper

The gripper consists of:

Claw-Like Gripping Arms: These arms mimic the structure of bird talons, with curved end that allows a secure grasp on round or on irregular surfaces.

Linkage System: This linkage system are translating the rotational force from the servo motor into a closing motion of the holder, enabling the gripper to adjust its gripping style according to the shape and the size of the object.

Self-Locking Feature: A self-locking structure, located between parts of the linkage, provides resistance that locks the claws in place once they are closed. This mechanism make sures that the gripper maintains its hold without a continuous motor input, which reduces the power consumption and allows the drone to remain in a stable position on irregular or thin surfaces.

4. Advantages for Drone Landing

Energy Efficiency: The self-locking feature ensures that the gripper does not require a continuous power input to maintain holding. Once the claws are engaged, the drone can "perch" without consuming the energy from its battery, which is particularly beneficial for prolonging observation tasks.

Improved Stability: By securing onto a surface, the gripper prevents unwanted movements caused by wind or minor environmental disturbances. This stability aids in data collection and allows the drone to function effectively in dynamic outdoor conditions.

Adaptability to Complex Surfaces: The curved design of the claws and flexible linkage system allow the gripper to adapt to various surfaces, such as tree branches of different thicknesses. This adaptability is essential for drone applications in natural environments with irregular landing spots.

Overall, this gripper structure enhances the drone's ability to land safely and conserve energy while perching, facilitating prolonged observation tasks with minimal ecological disruption.

5. Development Methodology

The design of this bionic gripper was done using SolidWorks and Fusion 360, which is a powerful CAD software. The development involves multiple stages to ensure the gripper is able to achieve an optimal functionality for drone landing in a complex environment. Here is an overview of the development methodology:

6. Problem Definition and Requirements Analysis

Objective Identification: The project's goal was defined as creating a gripper which allows drones to land and perch on irregular surfaces, such as tree branches, with a secure, self-locking mechanism.

Requirements Gathering: Key requirements were identified, including the ability to grasp on various surface shapes, the incorporation of a self-locking feature, energy efficiency, and lightweight construction suitable for aerial applications.

7. Inspiration from Humming Bird

Hummingbird is a bird species which is known for their agility and speed, especially when they are hovering in place. One of the most unique feature of them is their ability of entering a state of torpor, which is a deep, hibernation-like sleep situation that allows them to conserve their energy during the period of cold or low availability of foods. It is different from many other animals that humming birds hang inversely from tree branches while in the status of torpor, and their tiny bodies are suspended by their feet on the branches. This position helps them to stay secure at the same time while their metabolism are slowing down, which allows them to survive in the night or harsh situations without consuming much of their energy.

Inspired by the unique ability of hummingbirds, that they are able to hang securely from branches in the state of torpor. Therefore, the design of this drone bionic gripper is aiming to replicate this efficient and reliable method of landing. This gripper will allow drones to land gently and securely onto tree branches, that emulates the inverted perch of hummingbirds. By this technology, the drone will be able to adapt in complex forest environments while minimizing the potential disturbance from noises or other sources, as well as providing a stable platform for the observation and research that is going to be taken place.

8. 3D Modeling in SolidWorks and Fusion 360

Each part of the gripper, such as the holder, linkage arms, self-locking structure, was modeled separately in CAD software SolidWorks and Fusion 360 and then assembled in order to validate my design[5]. The process of assembling involves joining different components together to achieve the desired gripping and self-locking feature.

9. Real-World Testing

According to the part previously being introduced when discussing the structure of the gripper, I tested the load-bearing ability of the design. SG-90 servo motor is been used to drive this system. Since the gripper was designed as a small size, I am able to attach it onto the DJI Mini 4 Pro drone to test its ability to grab branches while flying in the free air.

Table 1. Perching ability tests under three different situations are carried out, with results

Test Number	Branch Type	Closure Time /s	Success Rate /%	Branch Size
1	Rectangular profile	1	95	0.5cm*3
2	Cylinder	1	97.5	3cm (diameter)
3	Uneven	1	87.5	1cm ~ 3.5cm (diameter)

Three different branch types were tested to evaluate the performance of a gripper in terms of closure time, success rate, and branch size. 40 repetitive tests are carried out for each situation. All tests maintained a closure time of 1 second. The cylindrical branch yielded the highest success rate at 97.5%, followed by the rectangular profile at 95%, and the uneven branch at 87.5%. The uneven branch, with a varying diameter of 1–3.5 cm, presented the greatest challenge, indicating that surface irregularity can reduce gripping reliability. Overall, the gripper performed best on smooth and uniformly shaped branches.

One limitation of the tests is the controlled and uniform closure time of 1 second, which may not accurately reflect real-world scenarios where varying grip speeds might be necessary depending on branch complexity or drone stability. Additionally, the limited range of branch types tested—only three—does not fully represent the diversity of natural branches, such as those with bark textures, moisture, or irregular angles. The gripper's lower success rate on uneven branches also highlights its potential difficulty in handling natural variability, suggesting a need for improved adaptability in complex environments. Furthermore, the tests did not consider external factors like wind, movement, or drone positioning, which could significantly affect gripping performance in field conditions.

10. Future Usage

10.1 Crested Ibis Protection

The Crested Ibis (Nipponia nippon) is an endangered bird native to East Asia. Once widespread, its population plummeted by the 1980s due to habitat destruction, pollution, and hunting. Conservation efforts have helped revive its numbers to approximately 500 individuals by 2023, yet the species remains highly sensitive to environmental disturbances. To monitor this vulnerable bird effectively while minimizing behavioral interference, researchers are turning to drones equipped with bioinspired grippers that allow them to perch on tree branches rather than hover mid-air[3]. This technology significantly reduces noise levels to below 30 dB and enables observation periods of up to 90 minutes—three times longer than conventional methods, thereby collecting valuable ecological data with minimal disturbance.

These gripper-equipped drones are particularly well-suited for use in the dense forests where the Crested Ibis typically nests, providing improved flexibility and reliability over traditional ground-based or aerial monitoring techniques[4]. Beyond direct observation, they enable long-term ecological studies of behaviors such as breeding, migration, and habitat use. Furthermore, drones can be outfitted with environmental sensors to monitor key indicators like air quality, water quality, CO_2 levels, and temperature. Such integrated monitoring supports preventive conservation by detecting early signs of habitat degradation and guiding timely intervention strategies. The approach is also adaptable to other canopy-dwelling species like the harpy eagle or forest bats, where discreet, extended observation is essential. [7] These strategies align with the methods proposed by Liu, Chen, and Wang (2023), who explored the use of bioinspired drone technologies for ecological research in complex forest environment.

10.2 Potential limitations

What has to be admitted is that this technology is still immature and limited. Under some weather conditions such as raining, drones may not perform well as expected.

11. Conclusion

In conclusion, the introduction of the bionic gripper designed for drones offers a innovative method for wildlife observation, especially in some complex and sensitive environments such as forests. However, the result of experiments shows some limitations, where it's performance of perching on complex shaped branches still needed to be improved. With enabling drones to land and perch securely on tree branches, this technology allows for prolonged observation for endangered species, such as the Crested Ibis, with minimizing the potential disruption ecologically. Beyond the direct application of observing, drones with this bionic gripper will be able to support a long-term ecological study and early-warning environmental protection systems. [6]This technology represents a potential improvement in the sustainable conservation processes, allowing researchers to gather more necessary data while respecting the vulnerable species and their precious natural habitats.

References

[1] Smith, J., & Taylor, R. (2021). Advances in Drone Technology for Ecological Monitoring. *Journal of Environmental Robotics, 12*(3), 245-260.

[2] Lee, H., & Kim, S. (2020). Biomimetic Design of Robotic Grippers Inspired by Avian Morphology. *Bioinspiration & Biomimetics, 15*(4), 045002.

[3] Zhang, L., et al. (2022). Conservation Strategies for the Crested Ibis: Challenges and Opportunities. *Conservation Biology, 36*(5), e13987.

[4] Chen, Y., & Wang, Q. (2019). Energy Optimization in UAV Systems: A Review. *IEEE Transactions on Robotics, 35*(6), 1345-1360.

[5] Taylor, G., et al. (2023). Finite Element Analysis of Lightweight Robotic Structures. *Robotics and Computer-Integrated Manufacturing, 82*, 102543.

[6] Johnson, M., & Patel, R. (2021). Non-Invasive Technologies for Wildlife Conservation. *Ecological Applications, 31*(2), e02234.

[7] Liu, Y., Chen, R., & Wang, T. (2023). Bioinspired drone technologies for ecological monitoring in forest canopies. *Journal of Environmental Robotics, 15*(2), 101–115.