Bio-Inspired Landing Gear for UAV's

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Abstract: The largest surveillance drone has a battery life of less than one hour, therefore we have to land the drone in unconventional places to ensure the battery range. The landing gear that is currently in custom is replaced in the article as bio-inspired landing gear to the aforementioned issue. The landing gear work has been written with great attention to the weight of the drones and the effects they may have when they land in unexpected places. The bioinspired landing gear ought to be robust enough to support the UAV's weight as well as its componentry. They are made to land in unconventional places, such as slopes and tree branches. The bioinspired landing gear, is joined to the drone through a plate underneath. In order to address the issue of the UAV's battery consumption, the research idea of landing gear that may be utilized to land in a typical locations and effectively cut off the power supply for a while. The landing gear was 3-D printed of using PETG material for its efficient physical and chemical properties. The landing gear can be fabricated in accordance with the differences in drone sizes.

Keywords: Surveillance, Bio-inspired, Landing gear, Weight, Slope, Unconventional areas, PETG.

I) Introduction

Multicopters which are equipped with an autonomous arm are being employed more often for emergency response, transportation, environmental monitoring and expedited home delivery [1]. Unmanned Aerial Vehicle have found broad uses in several domains such as infrastructure inspection, network and communication, search and rescue, traffic monitoring and management, intelligence surveillance and reconnaissance [1] [2]. Unmanned aerial vehicles, or micro air vehicles, are growing increasingly and more important in a range of applications, including searching, rescue, and inspection. To meet the challenges of these applications, which include quick approaches and precise landings or perching, Technologies used by UAVs, such as those for route planning, must be further developed. [3] Although their range is restricted, unmanned aerial vehicles (UAVs) may be launched and recovered effectively using designated runways and artificially level ground. Alternative methods and strategies exist for using UAVs more widely. [4]. unfortunately, the UAV's onboard power supply is limited by its size and payload restrictions, which often leads to a brief flight duration. UAVs have restricted flight times because to their inefficient aerodynamics and high consumption of energy. Additionally, UAVs must be compact and impractical to carry large-capacity batteries, particularly for fragile craft. [5]. Meanwhile, while flight, how air and propellers interact would produce a considerable deal of acoustic noise, making it appropriate for covert operations such as spying. In reality, the UAV's endurance time may be significantly increased and its noise level lowered It would be able to fly and perch like birds. While its rotors are turned off completely or in part. The flying perching technique provides a practical fix for the existing problem. The evolution of fixed wing UAV landing systems with the ability to perch and gaze presents a viable remedy for the problems associated with current launch and recovery techniques. Because of this, UAVs may land in unfamiliar settings by using their legs to absorb shock and carry out [4].

Birds' biological control systems, in contrast to those of typical UAV controllers, have been refined over many years of organic development evolution. As a result, birds are capable of carrying out a variety of nimble flying activities, such as perching, with accuracy and durability. An eagle can swiftly and accurately finish capturing an action, whereas a seagull may land on a tiny reef with ease. As a result, we have excellent cause to look to nature for inspiration while developing UAV technology. Recently, a few bio-inspired methods regarding UAV positioning been published in the literature. A fixed wing UAV from MIT demonstrated a unique technique for perching on a power line, while Stanford University created an autonomous perching UAV system that can land on a vertical wall [6][7]. Additionally, the University of Pennsylvania created a sturdy perching and landing mechanism that resembles the way bird feet work [8]. They've also shown that they can perch successfully on a level surface. The University of Utah developed a passive perching system [9] that allows a UAVV to perch on a variety of shaped objects. The topic of UAV flight dynamics and control is currently receiving more attention and developments due to the huge potential for UAV application demonstrated by these latest research initiatives. However, up to now, the majority of research on UAV perching has focused on the biometric design of perching systems [3].

One intriguing approach that efficiently integrates directional attachments with climbing technologies is the Stanford Climbing and Aerial Maneuvering Platform, which helps overcome the limited endurance and limits on existing battery capacity of small-scale aerial robots. Additional examples of adaptive morphological design concepts for multimodal locomotion include the flying and walking robot DALER, which can travel on the ground by using its wings as legs. This allows for efficient and adaptable movement in a variety of contexts. Several aerial robotics systems that can perch and move in multiple ways in unstructured surroundings were investigated in the aforementioned projects. These tests demonstrated that for autonomously piloted multimodal UAVs, the dynamic transition between flight and landing is a crucial part of a whole flight operation [5].

A true bird claw has many functions such as landing, grasping, perching, scratching and capturing. However, only the perching and grasping functions are of interest for today’s flying machines [3]. Its great loading capacity and remarkable flexibility have been demonstrated through trials. The perching mechanism may perch on various outside targets including tree branches, wires, eaves, and spherical lighting by merging it with a quadcopter. The energy usage of the system while perched on them.
In order to enable perching on a target item, the research presents newly built bioinspired landing gear and perching mechanisms for rotary UAVs. After that, the power usage is completed. Utilizing analytical methods for analyzing robotic hand performance, we elicit behavior from a model bird foot in response to stresses imposed by perching and carrying activities.

II) Geometry

Designing the landing UAV equipment that was influenced by bird’s leg is done in CATIA involves a systematic process to ensure functionality and aerodynamic efficiency. Beginning by creating a 3D model of the UAV in CATIA, accurately representing its dimensions and mass distribution.

Birds frequently perch on branches, eaves, wires, and other raised structures in the natural world. They can find and watch prey that is approaching their surveillance area constantly, and when the chance arises, they can move rapidly to acquire food. On the one hand, they may sleep in relatively secure areas and save energy. Birds are excellent at conserving energy when perching, which enables them to do long-term hunting activities with high efficiency. This makes birds an excellent model for flying robots that want to reduce noise and preserve energy.

Creating fixed-wing UAV landing devices that can look up and observe might be a good way to address the issues with the existing launch and recovery methods. This allows UAVs to land in unexpected environments and perform a successful perched landing method by utilizing their legs to lessen the impact. An efficient landing requires a number of stages.

Fig 2.1 Perching Method

The UAV will face the identical phases for the perching approach that the birds do: the first phase. At this point, the UAV needs to locate an appropriate perch and move in that direction. Control of approach velocity: Before the landing system takes control, a UAV must execute a proper maneuver in the second stage to reduce or flare in order to change horizontal velocity to vertical velocity. Extension of the landing gear: The landing gear extends to seize the perch once the car has been positioned to the proper position. Reduce the amount of time the landing gear takes to reach the perch during the extension stage to reduce errors in the UAV's location or flight path caused by long-range variables like wind. To reduce collision with the perch, velocity matching will be used. Absorption of the impact: As soon as the end effector touches the perch, the perch joins the system and changes the dynamics as a whole. The mass, velocity, and landing gear of a UAV determine the contact force between the end effector and the perch. Reduced landing impact is necessary to protect the air vehicle, perch, and landing mechanism from harm. Through the application of the regulated force, the collision's energy is dissipated as work.

Controlled capture: once the entire energy of the vehicle has been dissipated, the position and orientation of the vehicle must be controlled so that it achieves a statically stable configuration. This can be performed by the secondary controller on the landing system which applies the required correction.

In the wild, birds often rest on branches, wires, and other tall structures. They can find and watch prey that is approaching their field of observation constantly, and when the chance arises, they can move rapidly to acquire food. They can, on the one hand, sleep in a reasonably secure and energy-efficient environment. Birds are excellent at conserving energy so they work long-term hunting duties with remarkable efficiency.

Generally speaking, birds are able to control their descent with flare maneuvers and wing flapping. The legs aid in takeoff assistance, landing cushioning, and positioning correction. Thus, it makes sense to plan the landing in a similar manner, assuming that the flight controller has the ability to employ propulsion and breaking to make up for changes in altitude before landing. Even hovering UAVs might find it advantageous to have legs since they allow them to perch on comparatively small structure. This makes them a fantastic model for flying robots looking to reduce noise and use less energy. A true bird's claw has many functions such as landing, grasping, functions are of interest for today's flying machines.

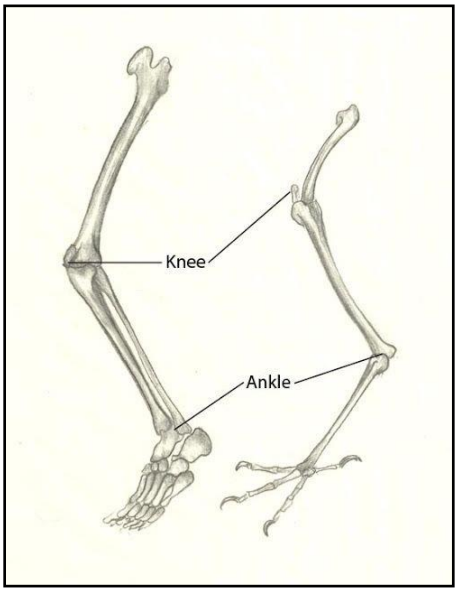

Fig 2.2 Bionic Inspiration

The structural morphology of the claw and the actuated grasping mechanism are decisive factors in the bird's ability to achieve a perching grasp. This research suggests a novel emotional solution to the aforementioned issues. Two types of bird-like claw perching grasping mechanisms, including the drive structure, leg structure, and claw structure from top to bottom, are built in response to the perching grasping behavior of birds.

The three primary components of a normal bird claw toe are the toe bone, toe pad, and toe tip. The base of each claw is where the toe pad is found. [6]

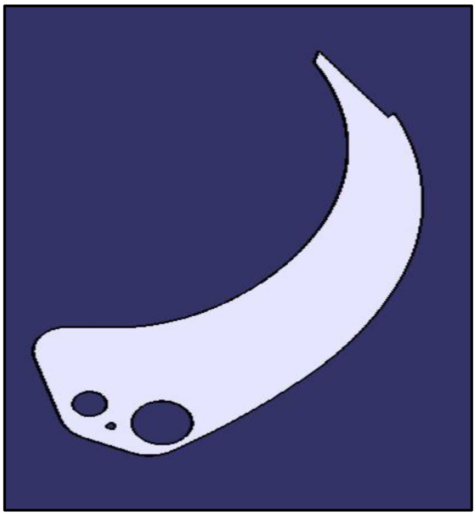

Fig 2.3 Tendon

The multipole rings that make up the toe bones may support unusual items with a diameter of roughly 20 cm. The tendons are made to withstand the force of a landing at atypical places because of their 20 mm thickness. The grippers that make up the toe bones are connected in series by tendons. Nonetheless, the intricate joint parts and pulleys needed for the cable-driven mechanism to direct the movements of the cables resulted in the system's bulk and weight. Furthermore, cables are frequently worn out, which shortens their lifespan. An integrated arc structure is suggested in order to get around such issues and make the structure simpler. It may be constructed from materials that allow for passive deformation and applied to a variety of objects with varying surfaces and forms. [2].

Many different toe arrangements exist in the claw of birds, often related to ecology and lifestyle with morphology varying from species to species. Anisodactyl toe Zygodactyl, [10] Heterodactyl are the main type of toe arrangements that are found in the birds legs which are capable according to their adaptations.

This design uses a different type of zygodactyl toe arrangement. There will be two pairs of toes on the front and rear of the claw. When the item is perched, the front toe, which is somewhat smaller than the rear toe, can form a perfect circle, adding an additional gripper to the landing gear.

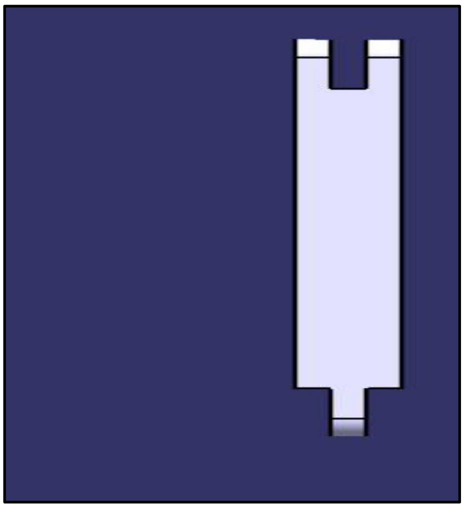

Fig 2.4 Fibula

The above shown picture is considered as the Fibula of the birds’ leg.

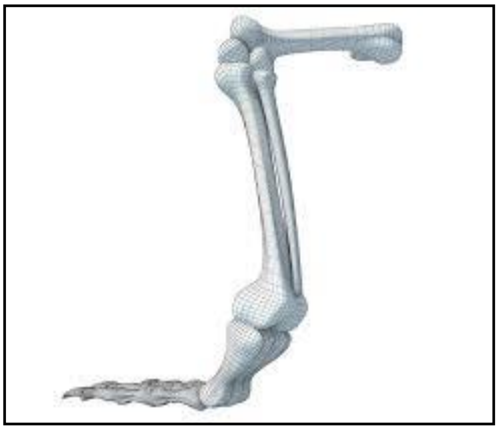

Fig 2.5 Feet Structure

The fibula, a 30-centimeter component, serves as the UAV's leg. A 3D printed plate that is positioned above the fibula or landing gear leg where the UAV is attached. The leg of the image above is attached to the hub, which is where the legs and toes meet. The spar in landing gear serves as primary load bearing structure distributing the UAV's weight and impact forces during landing. It is essential to maintaining the integrity of the structure and stability of the landing gear arrangement. For the spare to withstand the dynamic pressures brought on by the UAV's contacts with the ground, the material selection is critical from an engineering standpoint. The spar design considers variables like fatigue resistance and weight distribution.

And general toughness. To optimize the ratio of strength to weight of landing gear spars, modern UAVs employ cutting-edge materials and engineering processes, which enhances the overall performance and safety of the UAVs when operating on the ground. The advancement of landing gear technology is a reflection of ongoing attempts to improve the effectiveness, security, and dependability of UAVs.

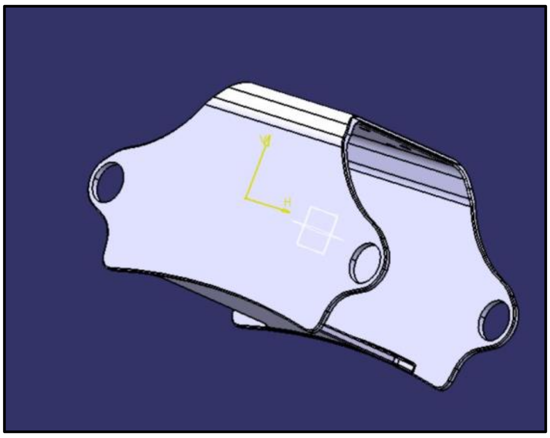

Fig 2.6 Hub

The main structural element that supports and joins the landing gear's component sections. The drone's landing gear usually consists of several parts, and the hub would be the focal point where these parts are covered. The landing gear legs have a point of connection and stability thanks to the structural element known as the HUB. Additionally, it could contain components for retractable landing gear systems, which would minimize landing gear interference during takeoff and landing.A bowed, pointed assembly found at the end of an appendage of landing gear, it serves as the UAV's foot. Usually, claws are employed for grasping. The Claw supports the whole payload that interacts with the UAV. The landing gear could have articulating joints or segments that provide a range of motion, enabling it to adjust to uneven ground when landing, in order to mimic the agility of a bird's claw. The drone's landing gear has a claw feature that actively grasps uneven or stable surfaces to help the drone perch.

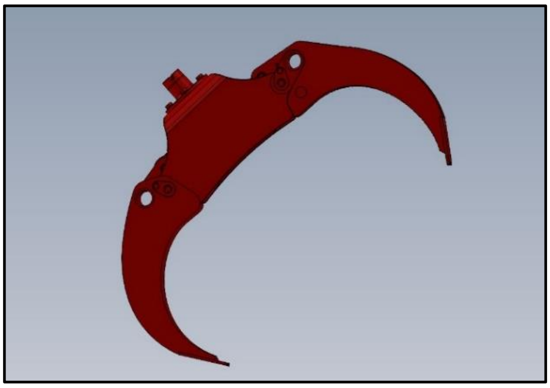

Fig 2.6 Claw

Inspired by the structural efficiency of a bird's leg, the landing gear material design goes through a rigorous modeling process to provide the best possible strength, durability, and weight characteristic. Bird's legs are a great model for engineers looking to improve landing gear performance because of their amazing blend of strength and low weight construction.

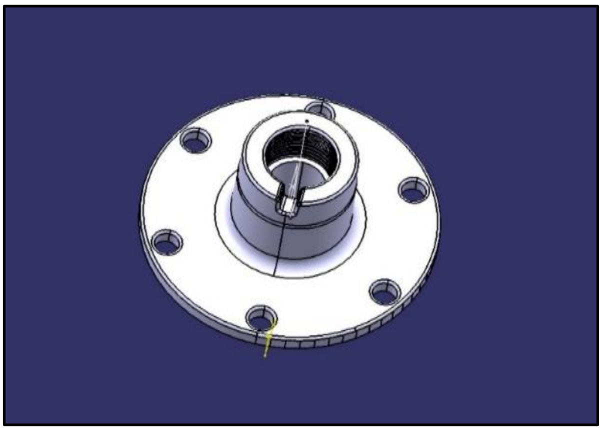

Fig 2.7 Joint Clamp

Advanced composite materials are commonly used in landing gear components to mimic the lightweight but structural integrity of bird bones. These composites—like carbon-fiber reinforced polymer—offer a high strength-to-weight ratio, which is essential for reducing the landing gear's total weight without sacrificing structural integrity. Achieving a balance that improves aerodynamic performance and fuel efficiency is the aim. Bird bones are characterized by hollow structures, which play a major role in their lightweight construction. To replicate this feature, engineers add hollow pieces to the landing gear assemblies. These hollow constructions preserve structural integrity while lowering the landing gear's total mass, which is essential for the UAV's overall efficiency.

Lattice-like patterns within the material design, additionally to hollow structures, aid in weight reduction and strength. To ensure that ensure that the landing gear can absorb and disperse impact forces during landings, the lattice design increases the landing gear's load-bearing capability while retaining flexibility. Because hollow bones make up the majority of a bird's leg's structure, it is renowned for being robust but lightweight. Engineers use advanced lightweight material to approximate this in the conceptual design of the landing gear.

For example, alloys or composite materials, to get a high strength-to-weight ratio. The landing gear components' hollow or lattice-like construction decrease weight even further without compromising structural strength. The choice of materials is seen as the most crucial stage in the creation process as it has a direct impact on the cost, durability, and performance of the product or its components. Fused filament manufacturing method, which uses 90% less material and produces almost Netscape components with less waste, makes 3D printing an environmentally friendly procedure. Additionally, this method produces the intricate and complicated pieces without the need for expensive molds. [11].

Additive manufacturing is defined as the process of linking materials to create three-dimensional components. Among the most typical materials used with regard to 3D printing is polyethylene terephthalate glycol [PETG]. Additionally, it is incredibly sturdy, making it possible to print items more quickly can operate very well in applications involving food safety or at high temperatures [12].

Moreover, PETG's low forming temperature level makes it simple to vacuum, pressure-form, and heat bend. As a result, PETG has lately caught the attention of the community involved in fused filament fabrication (FFF) three-dimensional printing as a relatively innovative and promising material it functions really nicely. With FFF process conditions. [13]. Because of its better mechanical qualities than PET polymer and its simple 3D printing FFF method, PETG may be used for a number of purposes [13] [10].

Moreover, the machine process characteristics that have emerged as crucial are the infill density, print speed, and layer height, which are measured at 80%, 60 mm/sec, and 200 µ, respectively. Improved machine parameter values might be helpful in determining the PETG 3D print material's operating ranges for different applications [11]. The incorporation of carbon fibers results in a decrease in compressive strain values (up to 66%) and an increase in hardness and modulus values (up to 27% and 30%, respectively). In addition, the cyclic compression and model tests indicate a decrease in the values of the loss factor and damping behavior [4]. In their experimental investigations, Ferreira et al. [11] found that adding fibers increased the values of Young's modulus by 70.10%, but decreased the stress with standing capacity by 28.21% instead. [11].

Table 1.1 Properties of PETG

Parameter	Data
Filament diameter	1.75mm
Density of the filament	1.27 g/cc
Favorable working temperature	235 deg C
Bed temperature to be maintained	60 deg C
3D printing technique	Fused filament fabrication
Infill density	100%
Operating temperature	220◦C-250◦C
Layer thickness	0.17 mm, 0.23 mm & 0.3 mm

This paper suggests a robotic hand design, including the forearm that can be produced by 3D printing. It attempts to replicate hand functions, including as gestures and object gripping that are found in the genuine human hand. Tendon-driven mechanism, which uses tendons to connect the servomotors to the hand's fingers, is the actuation system mechanism that is employed.

Additionally, the control framework makes use of an Arduino micro-controller, which regulates the servo angles according to the input received from the flex sensor, a muscle sensor. Additionally, flex motion sensors are employed to control the mobility of the robot's fingers with the usage of five servomotors. Flex sensors mounted on a wearable glove are used by the sensing circuit (transmitting master circuit) to detect signals from human hand motion. The robotic hand receives motion signals from a distance, which are processed and sent by both the Arduino card and the Bluetooth module. In order to transform the motion signals into an appropriate format for the servomotors' actuation, the robotic hand will employ a second Bluetooth module in conjunction with an Arduino card (a receiving slave circuit) to receive the motion signals.

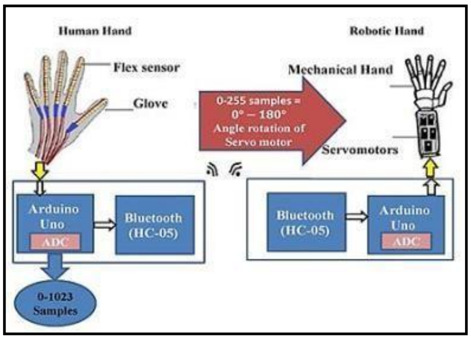

Fig. 2.8 Schematic Representation of Sensor

By receiving a signal from the flex sensor, the Arduino UNO can detect finger movements and analyze it before transmitting it. The 2.7-inch-long, basic flex sensor is employed as a motion sensor, and its resistance rises with its bend. The resistance of flex sensors changes as the degree of bending changes. [13] [14]. When a human finger bends, the flex sensors—which are affixed to a glove so that it may be worn by a hand—bend in reaction. The glove's installed sensors are a component of the transmitting (or master) circuit, which transmits the motion-sensing signals to the Arduino UNO card. The control algorithm will analyze those signals after it has received them and transform them into a format that can be sent to the receiving circuit. The Proteus simulator displays the transmitting circuit while the transmission is accomplished wirelessly with the use of a Bluetooth module, HC-05, that is linked to The Arduino card using AT instructions.

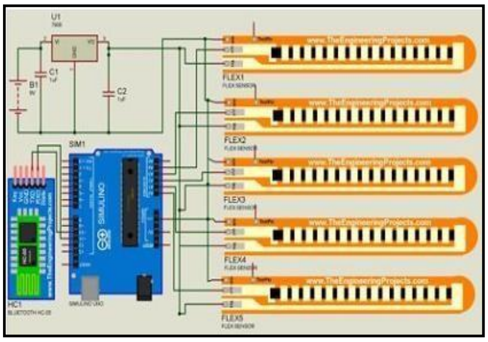

Fig. 2.9 Representation of Sensor

The receiving circuit, also known as the slave circuit, is made up of a Bluetooth module that receives the signals received by the master circuit and processes them once again using another Arduino card to act as control signals to the DC servomotors [16].

The master circuit provides the motors with rotational angles between 0 and 180 degrees, which correspond to the bending signals of a human finger. The Proteus simulator is used to simulate the slave circuit.

III) Testing

The perching mechanism, which has been built to attach to a test platform, comprises an upper section that grasps test objects and a bottom component that connects to a tension gauge. The frame is secured with the mechanism. This enables an exact demonstration of the perching mechanism's object-adaptability and loading capacity. The loading amount for the test is set at 4 kg as the UAV weighs around utilizing a safety factor of two and 2 kilogram. Independent testing makes use of unusual surfaces and things like tree branches and cylindrical shapes. Based on the results of the testing the mechanism of perching may be adjusted to a range of experimental things [15].

Under tension the bones in the toes are substantially stretched, and the toe pads are badly crushed and twisted. For this reason, the toes' greater passive deformability is required. Because of their flexibility and porous nature, the toe bones and toe pads are important in helping the perching mechanisms adjust for objects with vast cross-sectional areas. [16]. The claws are mostly responsible for the perching since there is a lot of relative sliding since the items' effective contacting surface is relatively tiny in relation to the toe pads. Ideal surfaces for low-hardness objects or tiny cross-sectional regions.

IV) Results and Discussion

Reducing the size and quantity of muscles required for gripping may offer several advantages, according to previous study. These include a general decrease in muscle mass and energy savings, yet, they could potentially have the opposite effect. In a possible loss of grabbing power. The imitation bird claw grabbing mechanism described in this work may be fitted to UAVs in the future to facilitate the transfer of flying items [17] [18]. In order to increase their range and perform specific duties like surveillance and search and rescue,

UAVs may also perch and stay on tree branches. Of course, its uses are not limited to UAVs; it can also be used to a wide variety of real-world scenarios. For instance, it may be utilized in the military, medical sector, aviation industry, intelligent industrial production, and daily life to substitute human hands in jobs demanding high volume and high quality completion by integrating auxiliary equipment like robotic arms and cameras. The second part of the study presents the structural design of the claw section of the bionic perching grasping mechanism, as well as the actuation method that was motivated by the two perching grasping mechanisms [19].

V) CONCLUSION

This work presents the design and presentation of a deformable bird inspired UAV perching mechanism that aims to enhance the durability, camouflage, and flexibility of the current flying perching robots. This research suggests a novel, flexible perching and gripping mechanism that is modeled after a bird's claw. The claw has four degrees of freedom and a distinctive form with two in the front and two in the rear. Findings indicate that it can be strongly adjusted, has a large loading capacity for a variety of items, and uses very little power when perched on targets. As a result, the application has confirmed that it is possible.

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