# Localization and Perching Maneuver Tracking for a Morphing UAV

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*Abstract*–**Autonomous vehicle control requires knowledge of the vehicle's states that often can only be estimated using sensor measurements. Several sensor types are typically used for the estimation process and each type often has its own sensing characteristics. This paper considers a novel morphing unmanned aerial vehicle (UAV) that is capable of changing its configuration in-flight and using aerodynamic forces to perform a perching maneuver. This maneuver could allow the UAV to perform planted landings and enable the vehicle to land in new locations, such as on building rooftops. However, this task requires the system controller to have accurate knowledge of vehicle states, especially with respect to the landing location. Visual sensors are required for identification of the landing site and to provide the relative positioning information that is critical for autonomous landings when uncertainty exists in the landing coordinates. Such information is unavailable from either a global navigation satellite system (GNSS) or inertial measurements to sufficient accuracy. The key objective of this research is to develop a foundation for the control of an aircraft that is highly nonlinear. This paper investigates the use of a set of linear motion models to represent the full range of nonlinear dynamics for an aircraft performing a perching maneuver. Simulation data are presented and their results discussed.**

## I. Introduction

Autonomous flight of an aerial vehicle is a challenging task that encompasses many aspects of modeling, design, performance, and control. New technologies and advancements in aircraft design are continuously being developed and incorporated into these systems to increase performance. This additional performance could also be used to enable new missions that have not been possible previously. Autonomous aircraft should be able to navigate and localize within their environment without operator input and should also be able to land despite possible uncertainties in the location of the landing coordinates. Critical aspects of the landing procedure are the detection and determination of the landing site and controlling the aircraft along a landing trajectory to safely arrive at the site. This paper discusses the estimation and localization aspects of autonomous flight as they apply to the landing of a morphing aircraft. This aircraft is capable of performing a perching maneuver to land, similar to the behavior of birds. This maneuver can be accomplished by allowing the airframe configuration to morph in-flight to provide the lift and high angles of attack desired for this task while maintaining a high degree of controllability.

The task of combining and interpreting all the sensor measurements presents a challenge that an autonomous controller must overcome to reliably direct the vehicle. Many technologies may be used to provide positioning or orientation information about the system. Increasingly popular are electromagnetic methods, such as global navigation satellite systems (GNSS) that are often used for wide-area positioning while other sensors are more often used for slight motions or attitude changes, such as inertial measurement units (IMU). These methods often differ in timescale stability. For instance, GNSS solutions typically maintain the same level of accuracy over a very long time period, while long-term IMU measurements suffer from incremental errors creating drift in the measurements. The vehicle controller must also incorporate alternative sensing methods to determine position solutions in the event that GNSS signals are unavailable or unreliable. Additional technologies also exist that help support precision landing. An example of such technology is that the instrument landing systems found at many airports, which broadcast directional information to aid the pilots in following the appropriate trajectory. Although this system is useful, one cannot always assume that such capabilities will always be available for unmanned aerial vehicles (UAV) landings in theater. Thus, autonomous aircraft should be able to identify the appropriate landing site and approach. Incorporating various sensing methods and amounts of data is critical for safe flight of autonomous aircraft. A challenge is to determine how combinations of various sensors, estimation and control methods may be used to allow the aircraft to achieve its desired performance.

Much research has been conducted and investigated various aspects of navigation and landing for UAVs. The platforms used in these investigations are typically either fixed-wing aircraft or rotorcraft. Aircraft landing is a challenging procedure that requires a vehicle to reduce its forward airspeed while maintaining sufficient levels of lift and control, and different aircraft types have various advantages due to flight characteristics and performance. Rotorcraft can have an advantage over fixed-wing aircraft as these vehicles are able to directly produce lift from thrust without the use of large lifting surfaces, such as wing airfoils. This ability allows rotorcraft to travel at low airspeeds during landing maneuvers, greatly aiding the landing procedure. In contrast to rotorcraft, fixed-wing aircraft must maintain a higher forward velocity to

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