

RÉPUBLIQUE ALGÉRIENNE DÉMOCRATIQUE ET POPULAIRE
MINISTÈRE DE L'ENSEIGNEMENT SUPÉRIEUR ET DE LA RECHERCHE
SCIENTIFIQUE

ÉCOLE NATIONALE POLYTECHNIQUE



Département d'Automatique

End of Studies Project

In fulfillment of the requirements for the degree of Engineer in Automatic Control

Icing Detection, State Estimation, and Control of Fixed-Wing
Drones

BOULASSEL Bilel & CHAABENI Ilyes

Under the direction of **Pr. TADJINE Mohamed**, ENP
and **Dr. SOUANEF Toufik**, Cranfield University

Presented and defended publicly on June 23rd, 2025

Jury Members:

President:	Pr. BOUKHETALA Djamel	ENP
Supervisors:	Pr. TADJINE Mohamed	ENP
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Département d'Automatique

Mémoire du projet de fin d'études

Pour l'obtention du diplôme d'ingénieur d'état en Automatique

Détection de givrage, estimation d'état et commande de drones à
voilure fixe

BOULASSEL Bilel & CHAABENI Ilyes

Sous la direction de **Pr. TADJINE Mohamed**, ENP
et **Dr. SOUANEF Toufik**, Cranfield University

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تُعدّ عملية التشغيل الموثوقة للمركبات الجوية غير المأهولة (UAVs) في الظروف غير المؤكدة والضارة تحديًا حرجًا، خصوصًا في وجود الجليد، والاضطرابات، والتفاعلات الديناميكية في أنظمة الوكلاء المتعددين. تطوّر هذه الرسالة إطارًا متكاملًا يجمع بين تقنيات التقدير الاحتمالي واستراتيجيات التحكم غير الخطي بهدف تعزيز الأداء والمرونة. يتم استخدام طريقة تعتمد على مرشح الجسيمات (PF) لتحسين دقة تقدير الحالة وكشف الأعطال المرتبطة بتكوّن الجليد من خلال تحليل التغيرات في معلمات النظام. ولتتبع المسار بشكل قوي في ظروف الطيران غير المؤكدة، تم تصميم مخطط تحكم يجمع بين مراقبين من نوع الانزلاق عالي الرتبة (HOSMO) وخوارزميات الانزلاق الفائق (STA)، مما يتيح التعامل الفعال مع الاضطرابات وتغيرات النموذج. وعلى مستوى الأنظمة متعددة الوكلاء، تم تقديم استراتيجية تحكم موزعة تعتمد على مراقبين ومتحكمين يعملون في زمن محدود ضمن بنية القائد-التابع، لتمكين سلوك جماعي سريع ومنسق. توضح الرسالة فعالية الأساليب المقترحة في تحسين قدرات كشف الأعطال، وزيادة متانة التحكم، وضمان تنسيق موثوق بين عدة مركبات جوية غير مأهولة.

الكلمات المفتاحية: مركبة جوية غير مأهولة ثابتة الجناح، كشف الجليد، مرشح الجسيمات، HOSMO، STA، التحكم في التشكيلات

Résumé

Le fonctionnement fiable des véhicules aériens sans pilote (UAV) dans des conditions incertaines et défavorables demeure un défi majeur, notamment en présence de givrage, de perturbations et d'interactions dynamiques dans des systèmes multi-agents. Cette thèse propose un cadre unifié combinant des méthodes d'estimation probabiliste et des stratégies de commande non linéaire afin d'améliorer les performances et la robustesse. Une approche basée sur le filtre particulaire (PF) est utilisée pour améliorer la précision de l'estimation d'état et détecter les défaillances liées au givrage en analysant les variations des paramètres du système. Pour assurer un suivi de trajectoire robuste en conditions de vol incertaines, une stratégie de commande est conçue en combinant des observateurs en mode glissant d'ordre élevé (HOSMO) avec l'algorithme super-twisting (STA), permettant de compenser efficacement les perturbations et les variations du modèle. À l'échelle multi-agent, une stratégie de commande distribuée est mise en œuvre, reposant sur des observateurs et des contrôleurs à convergence en temps fini, intégrés dans une architecture leader-suiveur afin de garantir un comportement coordonné et rapide du groupe. La thèse démontre l'efficacité des méthodes proposées pour renforcer la détection de défauts, améliorer la robustesse de la commande et assurer une coordination fiable entre UAVs.

Mots-clés: Véhicule aérien à voilure fixe sans pilote – Détection de givrage – Filtre particulaire – Mode glissant - Contrôle de formation

Abstract

Reliable operation of unmanned aerial vehicles (UAVs) in uncertain and adverse conditions remains a critical challenge, particularly in the presence of icing, disturbances, and dynamic interactions in multi-agent systems. This thesis develops an integrated framework that combines probabilistic estimation and nonlinear control strategies to enhance performance and robustness. An approach based on the particle filter (PF) is employed to improve state estimation accuracy and detect icing-related faults by analyzing variations in system parameters. For robust trajectory tracking in uncertain flight conditions, the proposed control scheme combines a high-

order sliding mode observer (HOSMO) with the super-twisting algorithms (STA), effectively managing disturbances and model variations. At the multi-agent level, a distributed control strategy is introduced, utilizing finite-time observers and controllers within a leader–follower structure to enable fast and coordinated group behavior. The thesis demonstrates the effectiveness of the proposed methods in enhancing fault detection capabilities, control robustness, and ensuring reliable multi-UAV coordination.

Keywords: Fixed-wing Unmanned Aerial Vehicle - Icing detection - Particle filter - Sliding Mode - Formation control

Dedication

*To my beloved parents,
For your unconditional love, endless support, and constant encouragement. Your sacrifices,
prayers, and belief in me have been the foundation of every achievement in my life.
To those closest to me,
Your presence, patience, and motivation have carried me through the most challenging
moments of this journey. Thank you for being my source of strength and comfort.
And to myself,
For the perseverance, resilience, and hard work invested over these past five years. This
accomplishment stands as proof of the sacrifices made, the obstacles overcome, and the growth
achieved. I am proud of the journey, and even more grateful for everything it has taught me.*

Bilel

*I thank Almighty Allah for giving me the resilience and perseverance during these five years
of hard work and commitment.
I dedicate this work to my beloved parents, whose unwavering support, boundless love, and
countless sacrifices have been my greatest source of strength throughout my academic journey.
Your prayers, encouragement, and belief in me have inspired me to pursue excellence and
sustained me every step of the way. I am profoundly grateful—your impact on my life goes
beyond what words can convey.
My dedication extends to my dear brother and sister, aunts, and loved ones. Thank you for
your steadfast encouragement and support.*

Ilyes

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*Our heartfelt thanks go to our supervisors, Professor **Mohamed TADJINE**, and Doctor **Toufik SOUANEF**, whose continuous support, profound expertise, and thoughtful guidance have been instrumental throughout this research. Their encouragement and critical insight not only enriched our thesis, but also significantly contributed to our academic and personal development.*

We would like to extend our sincere gratitude to the honorable members of the jury for taking the time to review our thesis. Their insightful remarks and constructive feedback are highly appreciated and will undoubtedly contribute to improving the quality and clarity of our work.

BOULASSEL and CHAABENI

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