RÉPUBLIQUE ALGÉRIENNE DÉMOCRATIQUE ET POPULAIRE
MINISTÈRE DE L'EDUCATION SUPÉRIEURE ET DE LA RECHERCHE SCIENTIFIQUE

ÉCOLE NATIONALE POLYTECHNIQUE -ENP-
CENTRE DE RECHERCHE EN TECHNOLOGIES INDUSTRIELLES -CRTI-

Département d'Automatique

End of Studies Project

For the attainment of the State Engineer Degree in Automation Engineering

---

Design and Control of a Quadrotor for SLAM Applications

BENAISSA Tayeb

Under the supervision of **Mr. BOUDANA Djamel** (ENP) and **Mr. ZABEL Abdelghani** (CRTI)

Publicly presented and defended on (23/06/2025)

Jury composition:

President:	Mr. CHAKIR Messaoud	ENP
Promoter:	Mr. BOUDANA Djamel	ENP
Promoter:	Mr. ZABEL Abdelghani	CRTI
Examiner:	Mr. TADJINE Mohamed	ENP

ENP 2025

Département Automatique / ENP, 10 Rue des Frères OUDEK, El Harrach 16200 Alger Algérie.

RÉPUBLIQUE ALGÉRIENNE DÉMOCRATIQUE ET POPULAIRE
MINISTÈRE DE L'EDUCATION SUPÉRIEURE ET DE LA RECHERCHE SCIENTIFIQUE

ÉCOLE NATIONALE POLYTECHNIQUE -ENP-
CENTRE DE RECHERCHE EN TECHNOLOGIES INDUSTRIELLES -CRTI-

Département d'Automatique

End of Studies Project

For the attainment of the State Engineer Degree in Automation Engineering

---

Design and Control of a Quadrotor for SLAM Applications

BENAISSA Tayeb

Under the supervision of **Mr. BOUDANA Djamel** (ENP) and **Mr. ZABEL Abdelghani** (CRTI)

Publicly presented and defended on (23/06/2025)

Jury composition:

President:	Mr. CHAKIR Messaoud	ENP
Promoter:	Mr. BOUDANA Djamel	ENP
Promoter:	Mr. ZABEL Abdelghani	CRTI
Examiner:	Mr. TADJINE Mohamed	ENP

ENP 2025

RÉPUBLIQUE ALGÉRIENNE DÉMOCRATIQUE ET POPULAIRE
MINISTÈRE DE L'EDUCATION SUPÉRIEURE ET DE LA RECHERCHE SCIENTIFIQUE

ÉCOLE NATIONALE POLYTECHNIQUE -ENP-
CENTRE DE RECHERCHE EN TECHNOLOGIES INDUSTRIELLES -CRTI-

Département d'Automatique

Projet de fin d'études

Pour l'obtention du diplôme d'ingénieur en Automatique

Conception et Commande d'un Quadrirotor pour des Applications de SLAM

BENAISSA Tayeb

Sous la supervision de **M. BOUDANA Djamel** (ENP) et de **M. ZABEL Abdelghani** (CRTI)

Présenté et soutenu publiquement le (23/06/2025)

Composition du jury:

President:	Mr. CHAKIR Messaoud	ENP
Promoteur:	Mr. BOUDANA Djamel	ENP
Promoteur:	Mr. ZABEL Abdelghani	CRTI
Examinateur:	Mr. TADJINE Mohamed	ENP

ENP 2025

Département Automatique / ENP, 10 Rue des Frères OUDEK, El Harrach 16200 Alger Algérie.

ملخص

يقدم هذا المشروع تصميم وتطوير طائرة رباعية المحركات ذاتية القيادة تعتمد على تقنية التموضع ورسم الخرائط البصري المتزامن (V-SLAM) . تم استخدام نموذج ديناميكي يعتمد على الكواتيرنيون مع تحكم متسلسل من نوع P-PID ، مطبق على وحدات التحكم في الطيران Pixhawk 4 Mini (بهيكل QAV250) و Pixhawk 2.4.8 (بهيكل X500) . تم تشغيل خوارزمية ORB-SLAM3 على جهاز Jetson Orin Nano باستخدام كاميرا Intel RealSense D435 ، حيث تدعم أوضاع التصوير Stereo و RGB-D، مع تقييم للأداء في الزمن الحقيقي باستخدام ROS . يتم في هذا العمل استعراض الأسس النظرية للنظام، وتحديات التنفيذ العملي، والتحقق التجريبي من فعاليته.

الكلمات المفتاحية: طائرة رباعية المحركات ذاتية التحكم ، PID ، الطيار الآلي PX4 ، Pixhawk ، V-SLAM ، ORB-SLAM3 ، ROS ، Nano Orin Jetson ، D435 RealSense .

Résumé

Ce projet présente la conception et l'implémentation d'un système de quadrirotor autonome pour la Localisation et cartographie simultanées visuelles (V-SLAM). Nous utilisons un modèle dynamique basé sur les quaternions avec contrôle P-PID en cascade, implémenté sur les contrôleurs de vol Pixhawk 4 Mini (configuration QAV250) et Pixhawk 2.4.8 (configuration X500). L'algorithme ORB-SLAM3 est déployé sur un Jetson Orin Nano utilisant une caméra Intel RealSense D435, supportant à la fois les modes stéréo et RGB-D, avec évaluation des performances en temps réel sous ROS. Les fondements théoriques, les défis pratiques de mise en œuvre et la validation expérimentale sont examinés en détail.

Mots-clés: Quadrirotor Autonome, Contrôle PID, PX4 Autopilot, Pixhawk, ORB-SLAM3, ROS, Jetson Orin Nano, RealSense D435.

Abstract

This project presents the design and implementation of an autonomous quadrotor system for Visual Simultaneous Localization and Mapping (V-SLAM). We use a quaternion-based dynamic model with cascaded P-PID control implemented on both Pixhawk 4 Mini (QAV250 configuration) and Pixhawk 2.4.8 (X500 configuration) flight controllers. The ORB-SLAM3 algorithm is deployed on a Jetson Orin Nano using an Intel RealSense D435 camera, supporting both stereo and RGB-D modes, with real-time performance evaluation in ROS. The system's theoretical foundations, practical implementation challenges, and experimental validation are thoroughly examined.

Keywords: Autonomous Quadrotor, PID Control, PX4 Autopilot, Pixhawk, ORB-SLAM3, ROS, Jetson Orin Nano, RealSense D435.

Dedication

This journey has never been just about reaching a destination—it was about growth, transformation, and the people who walked beside me. Over these five years, I've not only pursued knowledge but also discovered strength I didn't know I had, held up by those whose love and belief never wavered. To those who stood with me through every doubt and every triumph—this work is, above all, a tribute to you.

No individual is complete without the unwavering support of family—so it is only fitting that I begin there.

To my dear mother—thank you for your unconditional love, for every word of comfort, and for the silent strength that carried me through my darkest moments. Your sacrifices, patience, and prayers have shaped who I am. I only hope to make you proud and someday return even a fraction of what you've given me.

To my beloved father—thank you for showing me what it truly means to be a man — to be strong, humble, and steadfast. Your wisdom, quiet courage, and unwavering belief in me have given me the strength to chase this dream. You've always been my protector, my compass, and a living example of true resilience.

You are both the pillars of my life. Without your love and support, I would not be standing here today.

To my big sister—thank you for your unwavering support, your guidance, and the warmth you brought to my hardest days. You've always believed in me, even when I didn't. Your care, advice, and encouragement made more difference than words could ever say.

To my brothers Bilel, Younes, and Mohamed—you are not only my brothers, but my first friends and lifelong companions. I hope you chase your dreams with courage and heart, and I believe with all my soul that your future holds great success.

To all my family—Your love, presence, and support, in both small and big ways, have helped shape my journey. I carry your strength with me every step of the way.

To my teachers and mentors—each lesson you offered was more than knowledge; it was encouragement to think, to question, and to reach further. You sparked the flame of curiosity that led me here and helped shape the scientist and thinker I strive to become.

To every friend who stood beside me—thank you for your laughter, for your late-night support, and for reminding me that no success is worth anything if it isn't shared. Your presence turned pressure into motivation and isolation into camaraderie.

And to every student, every dreamer—this is for those who build, fail, learn, and rise again. To those who dare to make drones fly, and ideas soar, even when the skies seem unreachable. May you never stop reaching higher.

Tayeb

Acknowledgements

First and foremost, I would like to express my deepest gratitude to **Allah** for granting me the strength, patience, and perseverance to complete this project.

I would like to sincerely thank all the teachers who have supported and guided me since the beginning of my academic journey.

I am especially grateful to all the professors of the **National Polytechnic School (ENP)** for their dedication and the valuable knowledge they have imparted to me throughout my studies.

My special thanks go to the entire **Control Engineering Department**, whose quality education provided me with the knowledge and skills necessary to successfully carry out this project.

I am sincerely thankful to my supervisors, **Mr. BOUDANA Djamel (ENP)** and **Mr. ZABEL Abdelghani (CRTI)**, for their continuous guidance, encouragement, and insightful feedback throughout the duration of this work. Their expertise and vision have significantly shaped the direction and quality of this thesis.

I express my gratitude to the **Fablab Incubator of ENP** for offering access to prototyping tools and collaborative space, which were valuable in the hardware development and integration process.

My heartfelt thanks go to the members of the **CRTI Research Center** for providing the workspace, resources, and technical support essential for the experimental phase of this project. Special appreciation is extended to the technical staff who assisted during the real-time testing sessions.

I would also like to thank my colleagues and friends, particularly those who contributed to system integration and field experimentation. Your collaboration, technical discussions, and moral support have meant a great deal to me.

Last but not least, I extend my heartfelt gratitude to my family, whose love and unwavering support have been the foundation of my strength.

Contents