Precise Landing of an UAV in a Floating Platform using Data-Driven NMPC

J. Campanhã*†, M. Almeida*, A. Martins*†
* *ISEP, Instituto Superior de Engenharia do Porto, Porto, Portugal*
† *INESC TEC, Institute for Systems and Computer Engineering, Technology and Science, Porto, Portugal*

***Abstract*—This document is a model and instructions for LaTeX. This and the IEEEtran.cls file define the components of your paper [title, text, heads, etc.]. *CRITICAL: Do Not Use Symbols, Special Characters, Footnotes, or Math in Paper Title or Abstract.**

***Index Terms*—component, formatting, style, styling, insert**

I. Introduction

Precision landing of Unmanned Aerial Vehicles (UAVs) on unstable platforms, such as floating vehicles, is a critical capability for maritime operations. This skill is essential for maritime operations, where UAVs must land on moving and constrained surfaces. However, achieving consistent and reliable landings in such environments is challenging due to platform motion, unpredictable external disturbances (e.g., wind and waves), and limited landing space.

Despite ongoing advancements, there remains a gap in the literature regarding viable control methods that can ensure precise and stable UAV landings on dynamically moving platforms. Existing approaches often lack the robustness needed to handle real-world disturbances effectively, limiting their practical applicability in maritime scenarios.

To address these challenges, this study proposes a data-driven Nonlinear Model Predictive Control (NMPC) approach, powered by an Autoregressive Integrated Moving Average (ARIMA) system. This method allows for an optimal control of the UAV while predicting the platform movement over a short horizon, allowing the UAV to adjust its trajectory in real-time for precise landings.

II. Related Work

As mentioned, this work focuses exclusively on control strategies for landing unmanned aerial vehicles (UAVs) on moving or floating platforms. This task is naturally challenging, due to the dynamics of UAV, as well as, the unpredictable nature of the platform's motion.

In the literature, UAV landings on moving platforms have been a topic that has already been covered by different techniques from a control point of view, but when it comes to floating platforms, this is no longer so extensive. However, this chapter will still study these similar scenarios in order to ensure a more comprehensive understanding.

Many of the work related to the landing of a UAV, focus mostly in improving the agent's capability of understanding the scene and the location of the desired location, specially with the use of visual information. Therefore, one of the most practical solutions is to use a PID-based algorithm to ensure that it can perform the required task. This type of approach can be seen, for example, in the works [1]–[3].

Image-Based Visual Servoing (IBVS) control algorithms are also often used in the landing of UAVs, as done by Haohua Dong, in [4]. since they allow to directly control the UAV in the pixel plane, while at the same time, being robust to camera calibration errors. However, in the process of projecting the feature world coordinates of feature points, the depth estimation is lost in the modeling process, as described in the survey [5].

These approaches can be quite effective for simple, precise landings. Yet, in highly dynamic scenarios, such as on the moving platform, this method is often not enough, due primarily to the nonlinear characteristics of the environment and the lack of dynamic and visibility constraints, as mentioned in the paper of Kunwu Zhang in [6], and by Lingjie Yang in [7].

In this way, a more advanced, or a higher level controller that allows the desired landing states to be tracked is required, and currently in literature, there are two main approaches for this problem, the use of Model Predictive Control (MPC) algorithms, as demonstrated in [6]–[9] and the use of Deep Reinforcement Learning (RL), as shown in [10]–[13].

The predictive behavior and constraint capacity of the MPC, makes this algorithm relevant for this type of application. More specifically, the use of Nonlinear Model Predictive Control (NMPC), due to the inherent non-linear dynamics of the UAV [6]. The Robust NMPC, which is a variant that takes into account the uncertainties of external disturbances and the drone model, as explained in the survey [14], has also been studied such in the works [6], [14], since it enhances the overall reliability in real-world scenarios.

These MPC methods can also be combined with other types of controllers in a more complex framework. As in the case of the work [6] and [7], that combined both the strengths of IBVS and the MPC for landing on a moving platform.

In case of collaborative platforms, communication can be established between the platform and the UAV, which may be another robot such as a UGV [8] or USV [15]. This communication, supported by state estimators, can enable the MPC to make more accurate predictions for optimal actions. Although not the focus of this study, this same algorithm, can also be implemented on a platform side, if it is equipped with actuators or robotic arms that enable active response to the