Technische Hochschule Ingolstadt

Faculty of Computer Science

The Future of AI in Air Traffic Management: Coordinating Autonomous Airliners and UAM within Busy Airspaces using AI

Seminar Paper

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Affidavit

I certify that I have completed the work without outside help and without using sources other than those specified and that the work has not yet been submitted in the same or a similar form to any other examination authority and has been accepted by them as part of an examination. All statements that have been adopted literally or analogously are marked as such.

Ingolstadt, 11 May 2025

Signature

Abstract

The summary gives the reader a rough overview of the content (brief problem definition, approach, solution approaches and possibly key findings). The scope should be about half a page. This chapter is not mandatory and should only be considered optional.

Contents

1 Introduction

1.1 Urban Air Mobility (UAM)

According to European Union Aviation Safety Agency (EASA), urban air mobility (UAM) refers to an air transportation system for passengers and cargo in urban environments.It primarily consists of electric VTOL (eVTOL) aircrafts, with air taxis used for passengers and drones for delivery of cargos, surveillance, and photography. These aircrafts can either be remotely piloted or with a pilot on board [1]. If these aircrafts are capable of autonomous flying, it is considered a part of unmanned aerial vehicle (UAV).

1.2 Autonomous Airliners (AA)

Autonomous airliners represent a branch of UAVs, consisting of fixed-wing aircraft capable of flying and navigating without direct intervention of a human pilot, for passenger service. Although modern commercial airliners already automate approximately 93% of flight functions, there remains a growing demand to implement higher levels of autonomy [2]. Increased automation is seen as a path toward enhanced safety, greater scalability, and improved affordability.

1.3 Differences between UAM, AA and UAV

UAM differs from traditional aircrafts with its use of rotors, and the ability to take off and land vertically from almost anywhere with a suitable platform, such as vertiports, and helipads, whereas traditional aircrafts are mostly equipped with fixed wings and require runways to operate [3]. Its range of opperation also differs, with UAM operate in urban areas (intra- and inter-city) while traditional aircrafts are able to operate for long distance travel, but only to locations with runway availability. Fig. 1 shows the comparison between UAM, UAV and conventional aircrafts. Fig. 2 shows the distance which the aircrafts travel to and from, as well as the airspace it occupies.

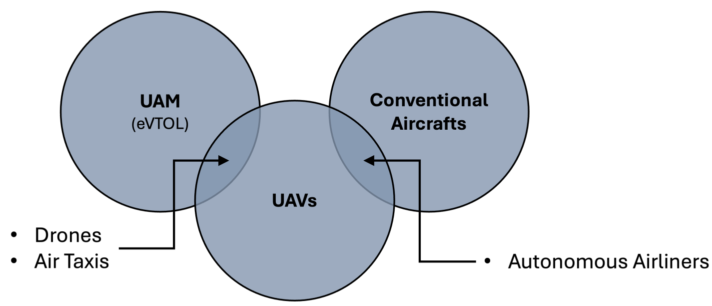

Figure 1: Venn diagram of UAM, UAV and conventional aircrafts.

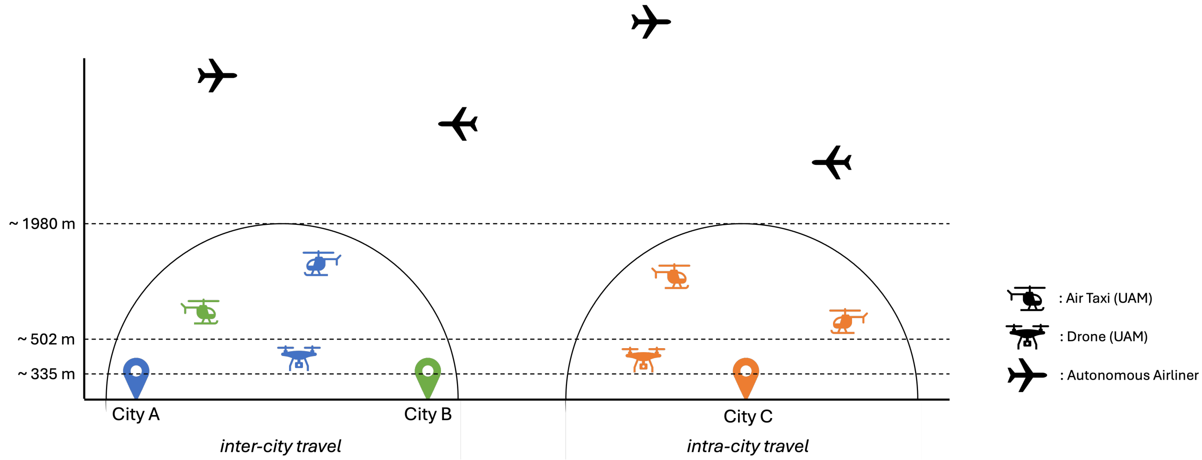

Figure 2: Mobility of UAM and autonomous airliners.

1.4 Air Traffic Management (ATM)

Air traffic management (ATM) is the aggregation of the airborne and ground-based functions required to ensure the safe and efficient movement of aircraft during all phases of operations, through controlled airspaces and on the ground at airports [4]. It comprises serveral components, including air traffic service (ATS), airspace management (ASM), and air traffic flow management (ATFM) [4]. Figure 3 shows the structure of ATM and the relationship between ATS, ASM, and ATFM.

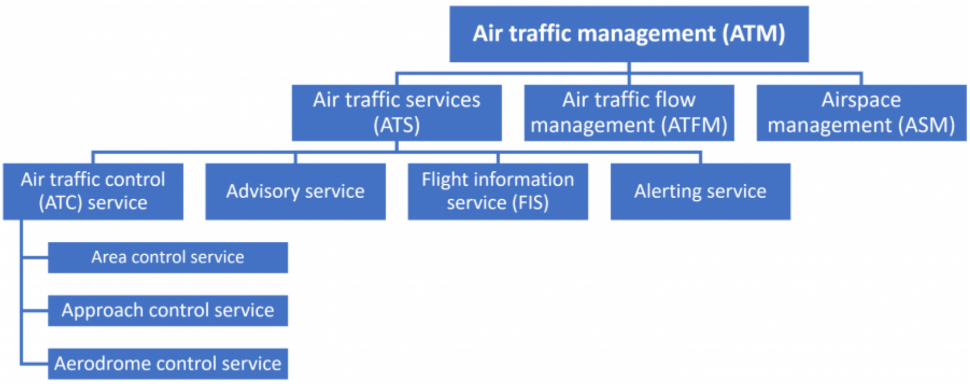

Figure 3: Structure of ATM [4]

Air traffic controllers (ATCOs), part of air traffic control (ATC) service, are responsible for directing aircraft safely and efficiently, managing takeoffs and landings, maintaining safe distances between aircraft en route and handling emergencies. Their role demands high levels of situational awareness, rapid decision-making, and the ability to manage multiple tasks under high stress conditions. These indispensable skills, such as judgement, flexibility and the ability to handle unexpected situations, remains critical and are not easily replicated by automated systems [5].

1.5 UAS Traffic Management (UTM)

UAS traffic management (UTM) is a system for safely managing UAV operations at low altitude. Separate from but complementary to ATS, it enables fucntions such as flight planning, authorisation, surveillance, and conflicht management to mitigate risks and ensure safe, efficient operations of UAVs. There is ongoing work to fully realize the benefits of UTM [6].

1.6 Challenges of integrtaing UTM with ATM

Integrating UTM into traditional ATMis complex but crucial for ensuring safe and efficient airspace operations, primary due to the differing nature of unmanned aerial system (UAS) and manned aircrafts. While UTM, designed to manage drone missions, , it must be integrated seamlessly into the existing ATM infrastructure to prevent accidents and enhance scalability. Both systems must work together, as unmanned flight systems need to detect and respond to other aircraft in emergencies, and vice versa [7].

The growing complexity of ASM, driven by the driven by the rapid expansion of commercial aviation, UAM, and UAVs, has led to increased air traffic volume. As air traffic rises, and with the limited capacity of ATCOs highlight the need for AI-based solutions, such as real-time data processing and predictive analytics, to improve system performance [8]. Despite existing automation, current systems often rely on rigid frameworks that lack the flexibility needed for dynamic environments [9].

Additionally, UAS have unique performance characteristics that complicate their integration into the air traffic flow, often resulting in suboptimal use of airspace capacity. UAVs typically operate across both controlled and uncontrolled airspaces, and since ATCOs only manage controlled spaces, the lack of oversight in uncontrolled airspace raises the risk of collisions or accidents. As a result, UTM systems are essential for ensuring safe and efficient UAV operations across all airspaces [10], highlighting the urgent need for scalable, flexible, and automated solutions in air traffic management.

1.7 Objective

The aim of this paper is to explore the potential of artificial intelligence (AI) in transforming ATM by enabling the safe and efficient coordination of autonomous airliners and UAM within busy airspaces. It examines the limitations of current ATM and UTM systems, highlight key AI applications such as dynamic sectorisation and digital ATCO assistants, and analyse the challenges involved. This paper also offers an outlook on the future of AI driven ATM and the path towards fully integrated, autonomous ASM.

2 Future of AI in ATM

3 Challenges of AI in ATM

4 Conclusion and Outlook

Acronyms

AI artificial intelligence. 3, 4

ASM airspace management. 2–4

ATC air traffic control. 2

ATCO air traffic controller. 2–4

ATFM air traffic flow management. 2

ATM air traffic management. 2–4

ATS air traffic service. 2, 3

EASA European Union Aviation Safety Agency. 1

eVTOL electric VTOL. 1

UAM urban air mobility. 1–3

UAS unmanned aerial system. 3

UAV unmanned aerial vehicle. 1, 3

UTM UAS traffic management. 3

References

[1] European Union Aviation Safety Agency. *What is UAM*. Accessed: 2025-05-05. URL: https://www.easa.europa.eu/en/what-is-uam.

[2] Samuel Vance, Evan Bird, and Daniel Tiffin. "Autonomous Airliners Anytime Soon?" In: *International Journal of Aviation, Aeronautics, and Aerospace* (Jan. 2019). DOI: 10.15394/ijaaa.2019.1402.

[3] Bianca I. Schuchardt et al. "Air Traffic Management as a Vital Part of Urban Air Mobility—A Review of DLR's Research Work from 1995 to 2022". In: *Aerospace* 10.1 (2023). ISSN: 2226-4310. DOI: 10.3390/aerospace10010081. URL: https://www.mdpi.com/2226-4310/10/1/81.

[4] SKYbrary Aviation Safety. *Air Traffic Management (ATM)*. Accessed: 2025-05-04. 2023. URL: https://skybrary.aero/articles/air-traffic-management-atm.

[5] EUROCONTROL. *Digitalisation and AI in Air Traffic Control: Balancing Innovation with the Human Element*. Accessed: 2025-05-05. Oct. 2024. URL: https://www.eurocontrol.int/article/digitalisation-and-ai-air-traffic-control-balancing-innovation-human-element.

[6] Federal Aviation Administration. *Unmanned Aircraft System Traffic Management (UTM)*. Accessed: 2025-05-10. 2025. URL: https://www.faa.gov/uas/advanced_operations/traffic_management.

[7] FlyNex. *UTM and ATM - This is the difference*. Accessed: 2025-05-10. Apr. 2020. URL: https://www.flynex.io/en/software-en/utm-and-atm-this-is-the-difference/.

[8] Anand Ramachandran. "Artificial Intelligence in Air Traffic Control Advancing Safety, Efficiency, and Automation with Next-Generation AI Technologies". In: (Feb. 2025).

[9] J. Meier et al. "Flexible Air Traffic Controller Deployment with Artificial Intelligence based Decision Support: Literature Survey and Evaluation Framework". In: *Deutsche Gesellschaft für Luft- und Raumfahrt - Lilienthal-Oberth e.V.* (2024). DOI: 10.25967/630258.

[10] Zsolt Sándor. "Challenges Caused by the Unmanned Aerial Vehicle in the Air Traffic Management". In: *Periodica Polytechnica Transportation Engineering* 47 (Dec. 2017). DOI: 10.3311/PPtr.11204.