Up, Up and Away - Investigating Information Needs for Helicopter Pilots in future Urban Air Mobility

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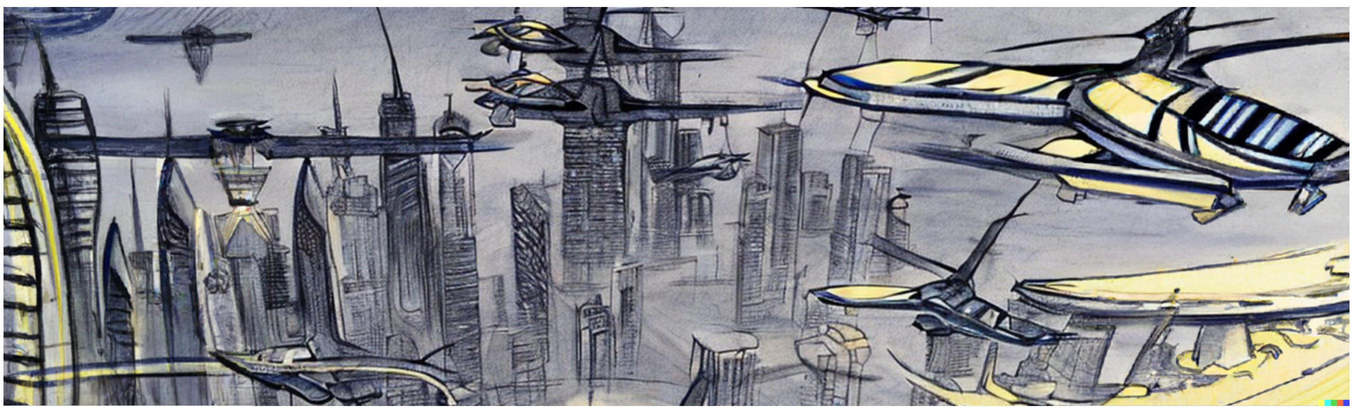

Figure 1: Sketch drawing of numerous air taxis above a city. Generated by DALL·E 2

ABSTRACT

This qualitative work aims to address the emerging challenges and opportunities through advanced automation and visualization capabilities in the field of helicopter piloting for future Urban Air Mobility. A workshop was conducted with N=6 professional helicopter pilots to gather insights on these topics. The participants discussed key themes, including information needs, user interfaces, and automation. The results unveiled novel opportunities and highlighted challenges for research on aiding helicopter pilots in the fields of obstacle avoidance, map visualization, and air traffic visualization, such as augmenting flight paths to increase their situation awareness.

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CCS CONCEPTS

• **Human-centered computing** → *Participatory design.*

KEYWORDS

Urban Air Mobility; Helicopters; Virtual Reality; Workshop

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1 INTRODUCTION

The advent of advanced automation and visualization technologies (e.g., augmented reality [14, 22]) is altering the nature of the piloting task for helicopter pilots. However, there is a lack of feedback for pilots regarding the design of interaction with automation and the information needs that can be satisfied with advanced visualization capabilities. While the final goal of Urban Air Mobility (UAM) is full automation [8, 37], in the near future, the inclusion of pilots and their engagement with automation will still be required. To support this transition, the presence of onboard pilots could be beneficial [2]. Hence, the perspectives of these pilots can provide valuable insights on how to tailor future air taxis to their needs and preferences, increasing their acceptance and situation awareness. Furthermore, gathering feedback from pilots can also help identify potential challenges and limitations of these technologies, which can be addressed through further research and development.

Therefore, in this work, an expert workshop with N=6 professional helicopter pilots was organized to gain insights regarding their information needs during the flight and regarding novel visualization modes. This work focuses on the following research question:

RQ1: *What are the **information needs** for helicopter pilots in future Urban Air Mobility with increasing automation and visualization capabilities?*

The results of the workshop indicate that the pilots perceived a high potential for advanced visualizations to improve obstacle avoidance, situation awareness, map visualization, and air traffic visualization in the context of UAM. These visualizations are particularly relevant for future scenarios involving multiple air taxis navigating through cities. One suggestion was visualizing the ego flight path and other air taxis' paths, which could enhance the pilots' flight behavior and situation awareness.

Contribution Statement.

- The main contribution of this work is the qualitative results of an expert workshop (N=6) showing that additional information would increase the pilots' situation awareness.

2 RELATED WORK

This work builds on previous work on helicopter interfaces and insights for UAM.

2.1 Interfaces to Support Helicopter Pilots

Pilots often encounter high workloads during flights. Therefore, new HMI systems were developed to support flight path control and navigation during adverse conditions [11]. One strategy to alleviate the high workload is to enhance the pilot's vision with additional information. In a degraded vision, Stanton et al. [35] found such a benefit in Head-Up-Displays (HUD). Friesen et al. [9] compared a baseline HUD with two other HUDs equipped with a conventional advisory display (showing when to move up to avoid obstacles) and a constraint-based display. While cognitive load tended to be lower and the situation awareness increased with the advisory display, the authors found no significant differences between the three HUDs in a study with 12 helicopter pilots. Stanton et al. [34] also found that a "Highway in the Sky" marker improved pilots' situation awareness, especially in degraded visual conditions. Also, Innes et al. [13] found pilots' landing accuracy was improved in various weather conditions with the addition of more visual information with only a minor additional mental workload.

Empirical research conducted by Waanders et al. [39] and Schmerwitz et al. [33] had shown that using a virtual representation of the surrounding environment during low visibility conditions can enhance pilots' situational awareness. A comparative analysis between Head-Down-Displays (HDD) and HUDs revealed that pilots preferred using the 3D environmental representation on the HDD while flying at high altitudes, while flying at low altitudes, they preferred the HUD, due to better spatial representation [25]. This finding aligns with recent qualitative research by Minotra and Feigh [23], which examined cognitive demands during ship-based landings. According to Lumsden et al. [21], the primary challenges for helicopter pilots are related to navigation, the visibility of the ship's landing platform, and the unpredictable motion of the ship. A recent study by Mehling et al. [22] found that augmenting the ship's visual cues with a see-through Head-Mounted Display (HMD) can significantly improve pilots' situational awareness and perceived safety for both high and low ship movements.

2.2 Human-Computer Interaction for Urban Air Mobility

Kim et al. [16] organized a workshop regarding UAM involving experts in the field of automotive engineering, the results of which were analyzed in follow-up publications by Lim et al. [19] and Kim et al. [15]. They found that participants identified a shift from safety and acceptance aspects in the early phase of UAM towards more comfort-related aspects in the mature phase. However, they did not provide concrete solutions. Edwards and Price [7] conducted a workshop with aviation experts and provided recommendations, including constructing a high-fidelity simulator to study passenger needs and the impact of rotor noise and vibration in the cabin. However, they did not focus on pilots' needs during the initial phase of UAM, where onboard pilots are still preferred [2].

3 WORKSHOP

An expert workshop was conducted with professional helicopter pilots (N=6) to gather insights into their current challenges and future information needs in the context of manual and automated operations. The workshop began by eliciting the participants' perspectives on their current challenges in helicopter piloting and subsequently shifted to a discussion of potential future interfaces and information that may be necessary to enhance their performance in future UAM.

3.1 Procedure

A consent form was provided to all participants before the workshop, outlining the use of a camera and microphone to record the discussion. Following the introduction of all participants, a brief overview of UAM was provided. The workshop was subsequently divided into three main topics for further discussion and examination. Therefore, we started the discussion with topics related to their current challenges with helicopter flights and later moved on to the potential challenges of automated helicopter flights:

- **T1** *Information needs during piloting*:
  In your opinion, what is the most important information displayed in the helicopter? And how have these displays changed over the past years?
- **T2** *User Interfaces*:
  What challenges do you have to deal with in current helicopter interfaces?

- **T3** *Automated helicopters*:
  How is the flight task changing with increasing automation in the helicopter?

For the time they spent during the 3-hour workshop, the participants were compensated with 30€.

3.2 Participants

The workshop took place at SimFlug München, a company offering simulator flights with several aerial vehicles for private and professional purposes. N=6 participants were recruited via mailing lists (see Table 1). On average, they were M=56.50 years old (SD=4.51; range: 54 to 67). Their experience in helicopter flights ranges from 3 to 300 hours per year in a flight simulator or an actual helicopter.

ID	Gender	Age	flight hours per year
P1	M	59	166
P2	M	54	3
P3	M	67	143
P4	F	61	50
P5	M	60	157
P6	M	56	300

Table 1: Workshop participants' demographic information. Flight hours were in a simulator or an actual helicopter.

3.3 Method

Analyzing the workshop followed the *thematic analysis* approach from Braun and Clarke [1]. First, the video and audio files of the workshop were transcribed. Subsequently, an initial coding round using inductive in-vivo coding, following the approach of Saldaña [32], was conducted by one of the first authors. Then, a second coding round, independent of the first one, was done by the other first author. Afterward, the two sets of codes were discussed among the researchers to elicit inconsistencies. Once the codes were established, they were copied onto a digital whiteboard for clustering and conducting the third (searching for themes), fourth (reviewing themes), and fifth (defining and naming themes) phase of the thematic analysis [1]. The initial clustering resulted in 14 main clusters. These clusters were then merged further into three themes: *varying information needs*, *information needs for pilots*, and *Automation*.

4 RESULTS

The results are divided into three chapters according to the groups deduced from the prior clustering mentioned above. The first chapter provides insights into different information needs. According to the participants, these change during different purposes, modes, and phases of the flight (e.g., planning phase, takeoff phase, climb phase, cruise phase, descent phase, approach phase, and taxi phase [40]). From here, the results shift from manual flights towards (partially) automated UAM. The advantages and disadvantages of automated flights are listed from the participant's point of view and their trust in this automation.

4.1 Flight Categorization for Deriving Information Needs

4.1.1 Purpose. The helicopter pilots' information needs highly depend on the flight purpose. [P2] mentioned that the information needs should be clustered into two groups: private and commercial flights. Generally, the required information increases from private to commercial flights as private flights are mainly performed during good weather conditions. Hence, according to [P2], only simple way-points are needed to orientate in private flights. On the contrary, commercial flights, especially rescue flights, are independent of weather and daytime; therefore, advanced techniques are required to support the pilots' situational awareness.

4.1.2 Mode. Furthermore, [P2] suggested distinguishing information needs between Visual Flight Rules (VFR) and Instrument Flight Rules (IFR). VFR refers to a flight only depending on sight, whereas IFR refers to a flight depending on the instruments when a visual flight is impossible due to bad weather conditions or nighttime flights.

4.1.3 Phases. Additionally, the information needs change during the flight phases (see planning phase, takeoff phase, climb phase, cruise phase, descent phase, approach phase, and taxi phase [40]). [P1] stated that helicopter pilots need more information during landing and take-off than when flying at constant altitudes and speed (*"During take-off and landing, it's important that I have the horizon. [...] that I know my capacity. And also climb rate, descending rate, and speed. When I am in the air at 90 knots straight, I don't always need these values."*).

4.2 Information Needs for Pilots

Pilots first mentioned altitude, speed, artificial horizon, and sinking/climbing rate as important information. However, besides these basic metrics, they also named additional information needs regarding specific flight situations, divided into three groups: *Obstacle Avoidance*, *Map Visualization*, *Air Traffic Visualization* and *Situation Awareness*.

4.2.1 Obstacle Avoidance. [P6] stated that current flight maps[1] do not include all relevant obstacles. For example, [P1] mentioned potentially dangerous power lines, as well as moving obstacles such as bird flocks. Further, all participants agreed that a map during the flight is essential to avoid prohibited air spaces and dangerous weather fronts. [P6] suggested projecting this map onto the helicopter's windows for better usability and situation awareness. This is in line with [P2], who suggested visualizing certain obstacles via a windshield display or HUD, which is especially important at night, as only a few obstacles are illuminated.

4.2.2 Map Visualisation. Similar to Obstacle Avoidance, all participants mentioned that a map during the flight is important for orientation and to avoid prohibited air spaces and dangerous weather fronts. [P6] suggested projecting the map onto the helicopter's windows for better usability. Here the visualization of the above-mentioned obstacles would also be desirable.

[1]https://www.faa.gov/air_traffic/flight_info/aeronav/digital_products/vfr/; Accessed: 18.01.2023

4.2.3 Air Traffic Visualisation. One of the most actively discussed information needs during the workshop was the visualization of other air traffic members. According to [P2], for a pilot, it is difficult to see other flying objects and estimate their trajectories. This seems to be easier during the night as these objects are illuminated. However, during the daytime, "*[..] you just see a grain of sand in the background and wonder: is it a bird, is it dirt on the windshield or is it actually an airplane [..]*" [P2]. He suggested displaying all relevant flying objects in the near 3D space to gain information regarding the airspace below and above the own helicopter, including the distances to the single objects. He also mentioned visualizing empty air corridors to see where it is safe to fly. In reference to this, [P5] proposed to indicate the flight paths of other objects and one's own trajectory. The own trajectory is important during airfield traffic patterns, where a prescribed flight path must be flown. In general, this shows the necessity to develop a mental model of the current air space's occupation in reference to their own location and increase their situation awareness.

4.2.4 Situation Awareness. However, not only the mental model of the far air space but also of the near space of the helicopter might enhance the pilot's situation awareness. Thus, during the landing, it is vital to understand the situation on the ground, particularly when the landing area is narrow (e.g., on a sports field or a road intersection). Pilots know the helicopter's size but have difficulties estimating how much space there is around the machine. Therefore, they often rely on the co-pilot to observe the space around the helicopter when descending. Additionally, information is required on whether the helicopter hovers forwards or backward during the landing procedure, as this movement can be subtle. According to [P5], this is especially a problem in low visibility conditions, as reference points are missing.

Another challenge during low visibility is the missing perception of the helicopter's lateral inclination. The helicopter tilts to the side during steering without the pilot noticing. The artificial horizon indicates this situation passively; however, [P2] mentioned that, to his knowledge, there is no system that actively alerts the pilot. He suggested a seat vibration for extreme inclination.

4.3 Automation

With emerging automation technology, the participants already partially experienced automation during their flights. For example, the stabilization of the helicopter is automated. [P5] even mentioned that on the helicopter he operates, some routes are automated except for takeoff and landing, requiring only the pilot's supervision. However, [P6] doubts that full automation without any pilot necessary will be possible in the next ten years. The participants agreed that during the first phase of UAM, pilots would be flying the air taxis, but automation might take over in the future. Still, they had rather contrasting opinions about the advantages and disadvantageous of fully automated helicopters. On the one hand, three participants stated that human supervision is always preferable to any kind of automation. They argue that one cannot fully trust auto-piloting. In particular, a computer would not be able to process all aspects of air traffic and, therefore, would not able to decide in a specific situation. On the other hand, [P5] envisions that when there are multiple air taxis in a single air space, it might not be possible to fly manually anymore as the situation is too complicated for a human to overview. [P4] and [P5] even stated that no pilots would be required in the future as everything would be automated. However, [P1] mentioned that with increasing automation, people rely on it blindly, which might cause over-trust in the system and lead to pilots unlearning how to fly. Nevertheless, a special focus should be on emergency situations. [P1] and [P5] argued that a human pilot has to intervene during an emergency as no automation can handle these unpredictable situations. Furthermore, [P5] thinks that no amateur, like an untrained passenger, could solve a complex emergency, thereby negating the possibility to enable passenger flights without a human pilot onboard or with remote piloting in an emergency However, when a remote pilot controls multiple air taxis simultaneously, [P5] noted that all air taxis under their control must land when a single aircraft has an emergency.

5 DISCUSSION

A workshop with N=6 professional helicopter pilots was conducted to elicit potential information needs for future UAM. All participants were familiar with automation in their job; however, only two of them believed that automation would be able to take over helicopter flights in the near future. There were still doubts about the ability of automation to make safe decisions in emergency situations. Yet, this is a common opinion according to Prahl and Van Swol [28], as human decision-making advice is often favored over automation. Especially, "*after receiving bad advice, utilization of automated advice decreased significantly more than advice from humans*"[28, p. 691] However, during manual flights, the participants saw a high potential for visualizations.

5.1 Differences in Information Needs

In general, the results suggest that the information needs of helicopter pilots are contingent upon the purpose, mode, and phase of flight. Specifically, it was found that private flights typically necessitate less information than commercial flights and that pilots require more information during takeoff and landing than when flying at constant altitudes and speeds. This finding aligns with research conducted by Schmerwitz et al. [33], who also found that helicopter pilots' situation awareness is primarily enhanced by information regarding the position, speed, acceleration, and spatial orientation. The participants in the workshop identified specific information needs for *obstacle avoidance*, *situation awareness*, *map visualization*, and *air traffic visualization*. Visualization of obstacles, in particular, is essential for avoiding prohibited air spaces and dangerous weather fronts, as previously noted by Peinecke et al. [26]. Additionally, pilots' difficulty estimating the space around the helicopter during landing situations highlights the importance of enhanced situation awareness and, thus, the potential benefit of visualization, as supported by Schmerwitz et al. [33].

Furthermore, with the forecasted growth in air traffic [10, 29–31], participants highlighted the need for advanced air traffic visualization to improve pilots' situation awareness. They emphasized the importance of communicating information on future trajectories. Visualizing the ego path and other air traffic was noted as being particularly important, which should be presented in an intuitive and easily accessible format, such as through windshield displays or head-up displays. Research has already looked into the visualization of trajectories [20, 27]. However, they neglect the automation aspect and the presence of other air traffic members in the UAM context.

The importance of path visualization during automation is supported by previous research in the field of automated vehicles. von Sawitzky et al. [38], Häuslschmid et al. [12], and Colley et al. [4] found that the visualization of future trajectories was preferred by participants over no visualization. Additionally, Wintersberger et al. [41] and Müller et al. [24] found that augmenting traffic objects relevant to the current driving scenario can increase trust. Although conducted in the context of automated ground transportation, these studies indicate that similar approaches may be beneficial in the context of UAM

5.2 Limitations

The main limitation of this work is that only six professional helicopter pilots were included in the workshop. While this does not necessarily decrease validity [36], the opinions stated by the participant could only reflect a small subpart of all relevant opinions. Additionally, our work is entirely based on the subjective opinions of the six participants and could be biased. While we put these into context, the stated opinions, therefore, have to be considered with caution.

5.3 Future Work

As there are only limited publications addressing HCI concerns of UAM [7, 15, 16, 19], future research should look into the effects of advanced information visualization on helicopter pilots and passengers within the context of (semi-)automated UAM. Special focus should be on visualizing future trajectories for the ego air taxi and other air traffic members, similar to related research on automated ground transportation [4, 12, 24, 38, 41]. Further research is needed to investigate the efficacy of these visualizations and their impact on pilots' performance.

Additionally, future research could be beneficial in visualizing the uncertainty of algorithms for the transitory phase from manually operating a helicopter to full flight automation. There has been some work in the automated vehicle domain studying uncertainty visualization [3, 5, 6, 17, 18]. However, none examine the uncertainty of visualizations for air taxis. While such a visualization is likely not relevant for passengers as they cannot take over control, this information could be beneficial for highly trained helicopter pilots assessing the helicopter's capabilities during automation.

6 CONCLUSION

Overall, we provide insights into pilots' information needs in the context of future UAM and the potential for advanced information visualizations to assist them. An expert workshop with N=6 professional helicopter pilots suggests that visualizing obstacles, other air traffic, and the ego flight path could enhance pilots' situational awareness. However, further research is required to investigate the specific effects of augmenting flight trajectories on pilots' performance and decision-making. With the increasing adoption of automation in UAM, it is important to consider the implications of new forms of visualizations for pilots and passengers alike. Moreover, the acceptance and perceived safety of UAM by passengers is a key factors for its success. Therefore, research on passengers' information needs and visualization should also be considered in future studies.

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