Integrating Polygonal Modelling and Situational Awareness for Safer Flight Operations

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ABSTRACT: Aviation safety is a fundamental aspect of the modern aviation industry, with situational awareness serving as a key factor in ensuring it. Situational awareness refers to the pilot's ability to assess and predict critical elements throughout all flight phases, including their own physical state, the technical condition of the aircraft, weather patterns, air traffic, and crew coordination. Its significance becomes particularly evident in scenarios where decision-making time is limited, such as during emergency situations. This article presents an enhanced methodology for quantifying pilot situational awareness using polygonal modelling, incorporating individual efficiency factors (IE) to personalize evaluations. The methodology takes into account visual, auditory, communication, and tactile information, as well as the speed of reaction to changes in flight. This approach allows not only to assess the level of awareness but also to identify weaknesses and improve pilot training while considering economic benefits such as fuel efficiency and error reduction.

KEYWORDS: Situational awareness, polygonal modelling, aviation safety, flight optimization, economic efficiency.

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1. INTRODUCTIONS

Situational awareness is a key aspect of aviation safety and operational efficiency. It encompasses the pilot's ability to perceive environmental elements, understand their implications, and predict their future state. As aviation becomes more complex, accurate assessment of SA is necessary to enhance pilot performance and optimize training methodologies. This study focuses on refining the polygonal SA model to account for individual pilot differences and exploring its economic benefits in aviation operations.

2. LITERATURE REVIEW

Previous research has emphasized the importance of SA in pilot decision-making. Endsley's theoretical model provides insights into information processing by pilots, while quantitative methods such as polygonal modelling have been employed for SA assessment. However, limited empirical validation exists for these models using real flight data. Additionally, economic aspects such as fuel savings and operational cost reduction due to improved SA have been underexplored.

Methods

This study involves two key phases:

- Experimental Validation of the SA Model: Data from real flight scenarios and high-fidelity simulators are analyzed to assess the effectiveness of the polygonal model. Key SA parameters—visual, auditory, communication, and tactile awareness—are measured under different flight conditions (takeoff, cruise, landing), with an additional focus on pilot-specific characteristics.
- Adaptation for Various Aviation Sectors: The model is refined for commercial, military, and UAV operations by considering variations in operational requirements, mission profiles, and interface technologies. Economic aspects such as fuel efficiency and error reduction are integrated into the analysis.

The improved SA model quantifies pilot awareness based on key contributing factors:

$$SA = (V \times W_v \times T_v \times IE_v) + (A \times W_a \times T_a \times IE_a) + (C \times W_c \times T_c \times IE_c) + (S \times W_s \times T_s \times IE_s)$$

Where:

- **V** – Visual awareness
- **A** – Auditory awareness
- **C** – Communication awareness
- **S** – Sensory (tactile) sensitivity
- **T_v, T_a, T_c, T_s** – Time factor for each type of awareness
- **W_v, W_a, W_c, W_s** – Weights (coefficients) determining the importance of each aspect

- **IE_v, IE_a, IE_c, IE_s** – Individual efficiency factors for visual, auditory, communication, and sensory awareness, respectively.

EXPERIMENTAL DATA

Flight Phase	Visual Awareness	Auditory Awareness	Communication Awareness	Tactile Sensitivity
Takeoff	0.85	0.75	0.65	0.60
Cruise	0.70	0.80	0.90	0.70
Landing	0.90	0.85	0.75	0.55

The model's weight coefficients are adjusted based on empirical data from real flights and simulations, considering the variations in pilot response times and cognitive processing.

Results and Discussion

Below are graphical representations of situational awareness factors across different flight phases:

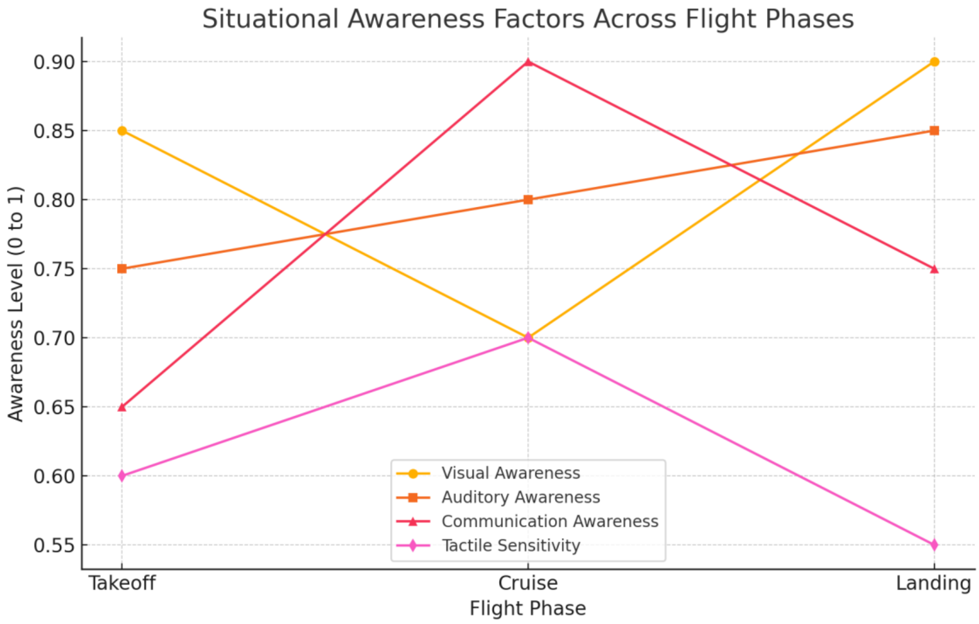

Figure 1: Situational Awareness Graph

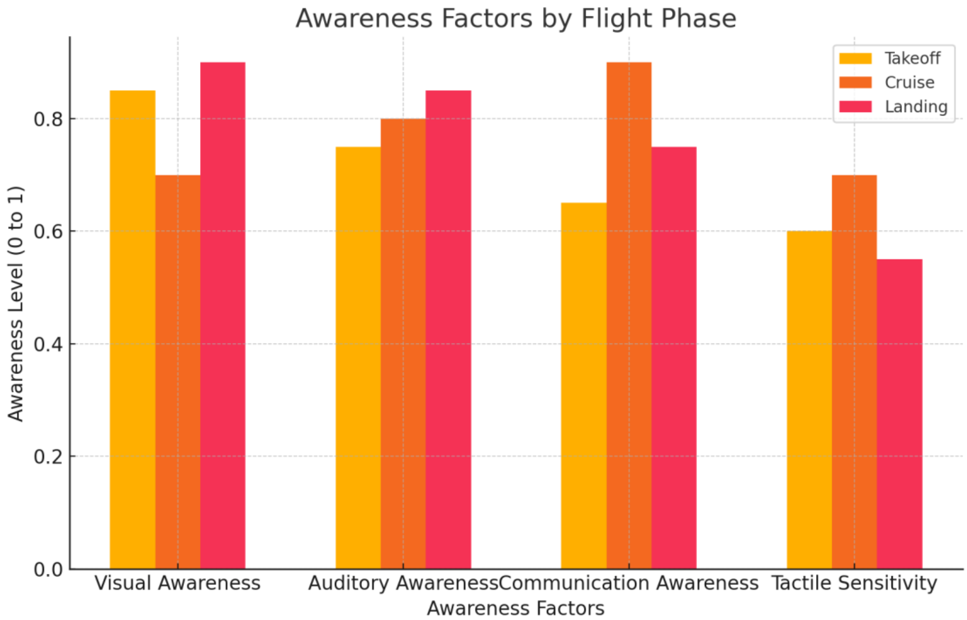

Figure 2: Awareness Factors by Flight Phase

Validation of the Enhanced SA Model:
Experimental results confirm that the modified model effectively quantifies SA levels while accounting for individual pilot differences. Adjustments in weight coefficients are necessary depending on the flight phase and aircraft type.
The implementation of the proposed methodology for assessing situational awareness offers substantial improving safety of flight and economic benefits for the aviation industry. Key benefits include:

Reduced Accident Rates: Improved situational awareness leads to fewer pilot errors, thus reducing the risk of accidents. This translates into significant cost savings related to aircraft damage, insurance premiums, and legal liabilities.

Optimized Training: By quantifying situational awareness and understanding the specific weaknesses of individual pilots, airlines can optimize training programs, ensuring that resources are focused on areas that need improvement. This can lead to more efficient and cost-effective training, reducing both direct and indirect training costs.

Increased Operational Efficiency: Enhanced situational awareness leads to more accurate and timely decision-making during flight, which can optimize fuel consumption, improve flight path efficiency, and reduce delays. These factors contribute to overall cost savings and higher operational performance.

Long-Term Cost Reduction: Over time, implementing such a methodology leads to reduced accidents, lower maintenance costs (due to fewer incidents), and optimized fleet management, resulting in long-term financial savings for airlines and aviation companies.

Improved Resource Allocation: The ability to assess and track situational awareness provides a basis for better allocation of resources during flight operations. Airlines can allocate more experienced crews to high-risk flights or use automated systems to assist pilots during critical phases, thereby enhancing both safety and efficiency.

Sector-Specific Adaptations:
Commercial aviation: Focus on workload management and fuel efficiency.
Military aviation: Emphasis on decision-making in high-stress scenarios.
UAV operations: Consideration of remote pilot latency and autonomous system integration.

3. CONCLUSION

The refined polygonal SA model demonstrates its applicability across different aviation domains, with tailored adjustments based on operational requirements and pilot-specific variations. Beyond improving flight safety, optimizing SA provides measurable economic benefits, including cost reduction and enhanced resource utilization. Future research should explore integrating AI-driven decision-support systems to further enhance aviation safety and efficiency, incorporating real-time pilot-specific data.

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