UDC 005.53:004.8+005.53-057.212]336.763.3(043.2)

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Comparison of the decision-making process between AI and human controllers during CDO using Point Merge Method

Compare the decision-making process of AI and human controllers during CDO, focusing on different metrics. The result of comparison is the examples of behaviour of analysed sub-systems.

AI vs Human decision-making efficiency.

The aviation industry has always been at the forefront of technological innovation, constantly pushing the boundaries to make air transport safer, more efficient and more accessible. From the earliest pioneer flights to the present day, aviation has undergone many technological revolutions, each contributing to the evolution of safer air travel. Human operators rely on experience, intuition and up-to-date avionics. However, these still can even lead to inefficiencies or errors, especially in high-stress situations. AI can quickly process vast amounts of data and make better decisions than human controllers.

Artificial intelligence is not a psychological construct, as it does not originate from the same underlying human cognitive or emotional processes. Instead, artificial intelligence may be considered a computational construct, as it is inferred from the outcomes of simulated aspects of human thought and decision-making, which are facilitated by data processing, machine learning techniques, and algorithmic principles [1].

The table structure compares the decision-making efficiency of AI and human operators (HO) (both pilots and air traffic controllers) during Continuous Descent Operations (CDO). Each subsystem is evaluated based on different properties, with a corresponding weight and efficiency mark on a scale from 0 to 1.

Table 1.

Comparative table of the DM efficiency of AI and HO

System	Property Description	Weight	System Mark (0-1)
Pilot (Human)	Reaction Time	0.2	0.7
Pilot (AI)	Reaction Time	0.2	0.95
ATC (Human)	Situational Awareness	0.3	0.8
ATC (AI)	Situational Awareness	0.3	0.85
Pilot (Human)	Proficiency in CDO	0.25	0.85
Pilot (AI)	Proficiency in CDO	0.25	0.9

ATC (Human)	Stress Handling	0.15	0.6
ATC (AI)	Stress Handling	0.15	0.95
Pilot (Human)	Communication Efficiency	0.1	0.75
Pilot (AI)	Communication Efficiency	0.1	0.9
ATC (Human)	Conflict Detection	0.2	0.7
ATC (AI)	Conflict Detection	0.2	0.92
Pilot (Human)	Fuel Management	0.15	0.8
Pilot (AI)	Fuel Management	0.15	0.9
ATC (Human)	Traffic Flow Coordination	0.25	0.75
ATC (AI)	Traffic Flow Coordination	0.25	0.88
Pilot (Human)	Adaptability to Changing Conditions	0.2	0.7
Pilot (AI)	Adaptability to Changing Conditions	0.2	0.85
ATC (Human)	Decision-Making Speed	0.2	0.65
ATC (AI)	Decision-Making Speed	0.2	0.95
Pilot (Human)	Error Recovery	0.15	0.75
Pilot (AI)	Error Recovery	0.15	0.85

System: Here, whether the system evaluated is the Pilot or ATC (Air Traffic Controller) and whether a human or AI operates is seen.

Property Description: The property or factor evaluated, such as reaction time, situational awareness, and proficiency in CDO, is listed here.

Weight: Here, each is assigned a weight to each property to indicate its relative importance in the decision-making process.

System Mark: An efficiency score between 0 and 1 for each system in each property is provided here, with 0 indicating low efficiency and 1 indicating high efficiency. The formula defines the weighted assessment:

$$X_{(subsystem)} = W*S \quad (1)$$

Each subsystem's weighted score is calculated by multiplying each property's score by its own. The results are as follows in table 2:

Table 2.

Pilot (Human):	Pilot (AI)	ATC (Human):	ATC (AI):
0.80	0.94	0.79	0.99

These calculations make it possible to depict a combined solution according to different schemes.

Scheme "AND”. The lowest value of all subsystems is accepted since all subsystems should give a positive solution:

min (0.80, 0.94, 0.79, 0.99) = 0.79

Scheme "OR”, where the highest value of all subsystems is taken because a favourable decision of one of the subsystems is sufficient:

max (0.80, 0.94, 0.79, 0.99) = 0.99

Majority system. For the majority system, the average value of all subsystems:

(0.80, 0.94, 0.79, 0.99) / 4 = 0.88

Based on these calculations, it is possible to decide on actions depending on the chosen scheme for integrating subsystem solutions.

In practice, combining decision-making efficiency from human and AI systems for air traffic management can be implemented in different operational strategies based on the selected scheme. Here is how this process might look:

Three working schemes options

1. **Scheme "AND"** in Practice (Minimum Performance-Based Approach): During the "AND" scheme, the system requires all subsystems to work at an acceptable level for safe, secure and efficient operations where a central system permanently monitors their performance. If any subsystem lowers a particular performance mark (in this case, 0.79), the entire process must be re-evaluated. This scheme puts safety and reliability first, but it leads to conservative decision-making. If one part of the system's efficiency decreases, it overrides to avoid potential risks. this scheme provides that all subsystems must work cohesively but may limit efficiency if any subsystem is stressed.

2. **Scheme "OR"** in Practice (Maximum Performance-Based Approach):

Scenario: The "OR" scheme allows for operation as long as at least one subsystem (e.g., AI or human ATC) performs functions at a high level.

The system relies on the strongest performing subsystem. If AI is performing optimally at 0.99, it can take the lead in managing CDO, with human operators in a supportive or supervisory role. This scheme maximizes efficiency by influencing the best-performing subsystem at any given moment, providing flexibility, and allowing the system to carry on working optimally even if one part underperforms. However, this approach may rely heavily on AI in scenarios where humans are not performing at their best.

3. **Majority System** in Practice (Average Performance-Based Approach):

Scenario: The majority system type is to average the performance across the subsystems, ensuring that the whole efficiency carries the same balance, but is not dependent on extremes. This approach creates a balance where there is no privilege for each subsystem. The decision-making process is designed to ensure that no subsystem's performance cannot impact overall outcomes. Within this collaboration, the workload is distributed equally, ensuring permanent performance.

Implementation in Practice:

Imagine a busy airport during peak hours, with aircraft continuously approaching for landing:

Scheme "AND" in Practice (Minimum Performance-Based Approach with Point Merge System): the system carefully monitors all subsystems. If the human ATC struggles to sequence incoming aircraft via the Point Merge System, AI can quickly provide trajectory corrections or manage the sequencing directly to maintain safe and efficient operations, i.e. it takes actions such as delaying landings, rerouting aircraft to secondary holding points, or adjusting the Point Merge arcs in order to prevent conflicts and accidents. This ensures that all subsystems work cohesively, but it can slow down operations when any single subsystem underperforms.

Scheme "OR": The operation carry on seamless, even if performance HO lowers, so AI carries most of the decision-making load. If the AI subsystem performance remains the same (e.g., 0.99 in efficiency), it solves tasks such as sequencing aircraft along the merge points, while human operators focus on communication with pilots and managing unforeseen events. If the human ATC subsystem cannot handle the growing workload, AI can continue controlling ensured sequencing of aircraft within the Point Merge System. On the other hand vice versa, human operators carry on decision-making while using AI support is not able at that moment.

Majority System: AI and ATC operators provide sequencing and managing aircraft arrivals using the Point Merge Method. AI may solve looping tasks such as adjusting aircraft along the point merge points or ensuring safe sequencing. HO will manage communication with pilots, keep with unexpected changes in weather or traffic, and oversee the overall operations safety. This approach allows to gain data-given tasks, like adjusting paths for flights in the Point Merge System, and helps to navigate complex or stressed situations.

AI shows appreciable speed and data processing. Nevertheless, in order to be ensured in the data resources and corrections provided to human operators consist of minimal errors. Thus, inaccuracies may endanger decision-making, and it must solutions to help make AI safer and to keep it in check:

- Installing an external monitor to assess the decisions of the AI engine from a safety perspective.
- Building redundancy into the process as a safeguard.
- Reverting to a default safe mode when unknown or dangerous conditions occur.
- Reverting to a full static program so that AI cannot evolve on its own. Instead, the AI would perform a safety analysis after the program is run and determine whether the program is safe.[2]

References

1. Prasad A.K.; Dileep Kumar M.; Macedo V.D.J.; Mohan B.R.; Achyutha Prasad N. Prasad, Anubhav Kumar (57205416540)
2. W. K. Youn, S. B. Hong, K. R. Oh and O. S. Ahn, "Software certification of safety-critical avionic systems: DO-178C and its impacts," in IEEE Aerospace and Electronic Systems Magazine, vol. 30, no. 4, pp. 4-13, April 2015, doi: 10.1109/MAES.2014.140109.