

Drone swarms and their potential within the Australian Defence Force

Lucas Page

Australian Defence Force

The onset of the war in Ukraine saw one of the most dramatic shifts in combined arms warfare since the introduction of the machine gun. This shift is attributed to the wide scale introduction of drones to the modern battlefield (Kagan *et al*, 2024). Principally the conflict is demonstrating drones pioneering new capabilities in reconnaissance, close air support and strategic strike with virtually zero risk to the operator. Furthermore, Air Marshal Chipman, former Chief of the Air Force, announced on the eve of the 2023 Avalon Air Show that Australia needs to consider and invest in low-cost mass-produced (LCMP) drones. The announcement acknowledged the sharp rise in the use of drones and their significant contribution to air power. Critically cheap UAVs have significantly lowered the bar for entry to high level military capability (Arnold, 2022) previously only enjoyed by large well-funded militaries, consequently, Australia must now innovate on the technology rather than simply follow global trends for the Australian Defence Force (ADF) to maintain its competitive and technological edge. One way for the ADF can achieve this is by moving from single drone systems to the introduction of swarms of drones acting in unison, combining their roles and capabilities for a collective output greater than the sum of its parts.

Single drone systems vs drone swarms

Currently, an operator is limited to flying one drone at a time, resulting in a system with zero redundancy and singular capabilities (reconnaissance or strike for example). Multiple drones require multiple operators. However, in contrast, a drone swarm is directed by one operator and could be assisted by artificial intelligence (AI) (Rickli & Mantellassi, 2023). With AI, the drone swarm can fly autonomously to a target to carry out multiple tasks concurrently (electronic warfare, reconnaissance and strike for example) or alternatively enable multiple simultaneous strikes on high value assets.

Autonomous swarm control

There are multiple methodologies for controlling a swarm of drones, however, a promising approach is distributed control characterised by 3 rules of Separation, Coherence and Avoidance (Reynolds, 1987). This sees the drones “linked together” like a spider web and are free to move in a region of air. This gives increased flexibility for dynamic environments and critically allows for seamless joining or removal from the swarm, enabling the swarm to continue even through combat losses.

Swarm dynamic target tracking and prediction

For a swarm to autonomously intercept a manoeuvring target, the swarm must be able to track and predict the future motion of its target. Traditional prediction methodologies usually see the path be matched to mathematical curves or go through reinforcement learning methods to learn the path slowly. However, modern techniques struggle with two key areas:

finding a balance between accuracy vs computing speed; and secondly, a requirement to be extensively tuned and trained in development before being deployed. To achieve this requirement, the drones require the recognition and memory of every possible target it could face to be accurate, which is a tedious and costly process.

These challenges inspired the development of a new AI model referred to as Biologically Inspired Fuzzy Brain Emotional Learning (BFBEL) (Muthusamy *et al*, 2024) This AI model works by replicating the emotional regulation of mammals by artificially representing the brain functions of the Amygdala and Orbitofrontal Cortex to learn and drive decision making. This process enables the AI to build a behavioural model of the system it is analysing in real time without external training to adapt a system to its changes. This model proved to have extreme adaptability and control, however, fundamentally the model was reactive to decision-making rather than predictive.

However, new research redesigned and extended the model, BFBEL-P, to enable future prediction for more efficient control of drone swarms (Page, 2024). The BFBEL-P enabled the swarm to build behavioural models on a target's complex and erratic motion (replicating evasion) in real-time during the flight and achieved target intercept while still avoiding obstacles, critically without any human input. Furthermore, the swarm then continued to track the target from a designated loitering altitude simulating reconnaissance capabilities (Page, 2024).

Considerations and potential applications

Adaptable behavioural models such as BFBEL-P hold profound potential to enable swarms of drones or other UAS systems to be controlled in large-scale operations. With the Defence Strategic Review (DSR) indicating threats within the region, the ADF could potentially face overwhelming numbers of light, medium and heavy armoured vehicles. While our current anti-armour weapons are highly effective and combat-proven, they will struggle to counter threats at this scale which could be mediated through the use of drones.

Furthermore, studies from (Centre for Strategic and International Studies, 2023) highlight that the Western military industrial base will face significant supply shortages during a full scale near-peer war. Given Australia's lack of domestic advanced missile manufacturing, our geographic isolation and strategic operating environment, this shortage will be extremely hard felt. However, the war in Ukraine has shown that advanced strike and reconnaissance capabilities can be achieved at extremely low costs through harnessing drones which could equally be exploited by Australia in such a scenario. Its implementation as alluded to by the former chief of the Royal Australian Air Force, Air Marshal Chipman will enable the ADF to employ asymmetrical tactics and strategically reshape our geopolitical environment. It will enable the ADF to apply exceedingly disruptive and tactically devastating actions within a high intensity battle space while reducing risks to our most valuable assets, our people.

Conclusions

The success of drones in recent conflicts highlights that they will form an integral part of any future fighting force. However, despite the profound potential of drone swarms' large questions are still being raised about their suitability and receive comparably little attention in current military doctrine. Nevertheless, if Australia wishes to maintain and regain its competitive edge, the proliferation of innovative technologies such as drone swarms must be given greater consideration for the ADF's future in our warfighting capabilities.

References

Arnold, C. (2021) Swarms of Trouble: The Hidden Threat of Consumer UAVs. *Air/Space* 1, bp16723318. <https://airpower.airforce.gov.au/blog/BP16723318>

- Center for Strategic and International Studies (2023). Preparing the U.S. industrial base to deter conflict with China. <https://features.csis.org/preparing-the-US-industrial-base-to-deter-conflict-with-China/>
- Kagan, F, Kagan, K, Clark, M., Hird, K, Bugayova, N., Stepanenko, K., Bailey, R. and Barros, G., (2024) *Ukraine and the problem of restoring maneuverer in contemporary war*, Institute for the Study of War.
- Muthusamy, PK, Tran, VP, Garratt, M, Annavati, S, Pota, H and Kok, JM (2024) Resilient flight control for a 32G nano helicopter, *IEEE Transactions on Industrial Electronics*, pp. 1–11.
- Page, L. (2024). Biologically inspired swarm dynamic target tracking and obstacle avoidance. *arXiv*. <https://arxiv.org/abs/2410.11237>
- Reynolds, CW (1987) Flocks, herds and schools: A distributed behavioural model,” in *Proceedings of the 14th Annual Conference on Computer Graphics and Interactive techniques*, pp. 25–34.
- Rickli, J-M and Mantellassi, F (2023) Artificial intelligence in warfare: military uses of ai and their international security implications, in *The AI wave in defence innovation*. Routledge, pp. 12–36.