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APPLICATIONS OF ARTIFICIAL INTELLIGENCE IN FIGHTER PILOT TRAINING

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APPLICATIONS OF ARTIFICIAL INTELLIGENCE IN FIGHTER PILOT TRAINING

AIM

1. The widespread proliferation of artificial intelligence tools, and the revolution it is bringing, stresses the need to harness this technology to maintain a competitive edge on the modern battlefield. In the air domain, Artificial Intelligence (AI) has already demonstrated its capability to challenge human performance. It presents itself at as an opportunity to not only address the current training system deficiencies but also push the limits of human performance further; AI can help produce more competent fighter pilots at a faster rate. The aim of this service paper is to highlight accessible applications of AI in fighter pilot training and to urge RCAF leadership to invest in the emerging field of AI-assisted pilot training.

INTRODUCTION

2. Like many other nations, Canada's aeronautical civil and military agencies are struggling with pilot shortages, which impacts the ability of the Royal Canadian Air Force (RCAF) to sustain its Force Generation (FG) requirement[1]. This problem is exacerbated by the fact that airlines are seeking candidates with the level of experience that constitute the instructor cadre of the RCAF, thereby creating an acute shortage of instructor-pilots and reducing the FG capacity of RCAF flying schools. Despite best efforts, the working conditions offered by the airlines, especially in terms of salary, outmatch what the RCAF can offer, making it challenging to reduce attrition rates. A detrimental effect of experienced pilots leaving is the reduction in the quality of pilot training; those leaving are replace with lesser experienced pilots. Inexperienced instructors do not produce graduate pilots with the same level of proficiency. In a context of economic compression and aging fleets, these graduate pilots must develop themselves within an unfavorable environment, subsequently becoming inexperienced instructors and perpetuating the spiral of fading experience within the RCAF at large. The Fighter force is particularly susceptible to this effect, in part due to an aging, maintenance-heavy fleet and other socio-cultural challenges, leaving the instructor cadre at a critical level of quantity and quality[2,3].

3. However, AI technology can be leveraged to augment pilot FG even in a context of personnel shortage. Even better, AI can reverse the experience-fading effect by providing a self-improving instructional tool. Applications with a focus on training are diverse and range from assisting pilots in their pre-solo flight training syllabus, to analyzing fighter pilot maneuvering and decision-making in complex combat scenarios. AI has the potential to provide individual, customized training to pilots, a condition envisioned as the ultimate training enabler for fighter pilots, akin to an Olympic-class coach-athlete relationship, which has been a desired training

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[1] Canada. Department of National Defence. "Managed Shortfall." 20 April 2018. https://www.canada.ca/en/department-national-defence/maple-leaf/rcaf/2019/01/managed-shortfall.html.

[2] Bronk, Justin. "CF-18 Fighter Force MINDS Study." RUSI, n.d.

[3] Tegler, Eric. "A Leaked Report Finds That Canada's Small Fighter Fleet 'Is in Crisis'." *Forbes*. Accessed 8 February 2024. https://www.forbes.com/sites/erictegler/2023/11/02/a-leaked-report-finds-that-canadas-small-fighter-fleet-is-in-crisis/.

environment yet out of reach due to the volume of instructors-mentors needed. AI can serve as that mentor, guiding a pilot from their initial flying training phase to their achievement of being the world's best fighter pilots.

DISCUSSION

Artificial Intelligence in support of Initial Flying Training

4. AI has the potential to enhance the sustainability of the RCAF by accelerating the training of new pilots without compromising the quality of training. The RCAF fighter force (FF) embodies the doctrinal concept of Force Generation in that it is relevant only if competent, and modern fighter aircrafts require substantial training (in the order of several years) before a pilot can be considered experienced, or "combat ready"[4]. Until now, the time required to achieve this status, and the various attempts at increasing training outputs, has been a tradeoff between the quantity and quality of pilots trained. A major obstacle to accelerating pilot training is resource availability; the number of pilots that can be simultaneously trained is limited by the availability of instructors, aircrafts and simulators. Given the current personnel and financial constraints, increasing these resources is not an achievable option. However, AI can assist in improving their efficiency.

5. Commercial aviation faces this challenge and initiative to solving it are promising. A study from the University of North Dakota investigated the use of virtual reality and artificial intelligence in training pilots[5]. Using virtual reality and AI-based simulator pre-training programs, the study showed that the level of transfer effectiveness between simulator and actual flying, during the pre-flying phase of training, was comparable between a group trained using AI-assisted instruction and a group who was human instructor led[6]. This finding is promising for any organization seeking to alleviate instructor shortages, and is particularly interesting in training curriculums composed of multiple phases of training like in the RCAF. Often, future RCAF pilots endure long wait times between phases where very few useful tools are available to prepare them for the next course. AI-assisted learning curriculums combined with professional or consumer-based training devices can allow pilots-in-training to begin developing their skills well ahead of formal instructor-led courses. Consumer-based simulator augmented by virtual reality, that can be installed on personal computers, have evolved and reduced the effect of negative transfer, *"enabling low-cost solutions for improving pilot performance"*[7]. The United States Air Force (USAF) applied such findings in a trial for the Pilot Training Next (PTN) project, which achieve positive results[8]. A simple application tested to have students learn basic aircraft maneuvers in a simulator while being supervised by an AI that guides the students through their maneuvers, rate the maneuver, gives an objective score to the performance, propose corrective

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[4] Canada. Department of National Defence. "B-GA-400-000/FP-001, Royal Canadian Air Force Doctrine: Air and Space Power." Royal Canadian Air Force Aerospace Warfare Centre, August 21, 2023.

[5] Guthridge, Ryan Paul. "Evaluating Virtual Reality and Artificial Intelligence as Solutions for Delayed Flight Progress in Aviation Pilot Training." *University of North Dakota*, August 2022. https://www-proquest-com.cfc.idm.oclc.org/docview/2722778829? .

[6] Ibid.

[7] Ibid.

[8] Atherton, Kelsey D. "How AI Could Help New Air Force Pilots Avoid Costly Mistakes." *Popular Science*, 15 March 2022. https://www.popsci.com/technology/air-force-artificial-intelligence-pilot-training/.

actions, all without human instructor involvement. Self-learning in aviation is not typically encouraged; unsupervised training can lead to erroneous habits being learned by the student and it takes more effort to correct faulty behaviors then to teach appropriately from scratch. AI is able not only to mitigate this effect but also reach the same level of behavioral learning then supervised training. In a context where the level of experience of the instructor cadre is decreasing, consistent and objective student rating has significant benefits to countering negative transfer of learning.

6. There are others secondary benefits to the technology. First, AI is consistent, compared to the variability in assessment skills of human instructors. Secondly, it can identify deficiencies, but more importantly quantify them, which is difficult for a human instructor[9]. Lastly, monitoring the progress of a large number of students can be challenging for a training establishment, but here again AI can monitor virtually infinite number of students. An AI-assisted training curriculum could therefore free human instructors to teach more advanced flying skills and cognitive abilities like airmanship, therefore increasing the overall output in both quantity and quality of the training system.

7. Even if AI can alleviate the instructor shortage challenge, the rate of training will still be limited by simulator availability, unless massive investments are made. This issue can be mitigated by a different approach to scheduling. If human instructors are not required, the availability of simulators can be increased, given it can run extended hours outside of typical workdays. A staggered use of simulator for AI-assisted training therefore does not incur additional strain on the instructor cadre. As mentioned earlier, there is also a case for the use of consumer-based simulation system which as demonstrated potential for learning to operate some avionic systems. Incorporation of such systems could replace training events traditionally carried out in accredited simulators, thus increasing simulator availability further for more technical learning.

8. In a small organization like the RCAF, training is normally standardized, delivered in a "batch training" style where everyone must learn at the same rate. However, projects like the USAF PTN are increasingly focusing on learner-centric model of training, which allocates training resources according to each pilot's learning curve, strengths and weaknesses. Such an approach undoubtedly produces more and better pilots, but can be demanding on the instructor staff. AI can fill the gap, tracking individual student-pilot learning profiles and recommending an appropriate training curriculum to maximize learning, without additional burden on the staff[10].

Artificial Intelligence in support of advanced Fighter Pilot training

9. Utilizing AI for advanced fighter pilot training can reap the benefits of the same principles discussed above. Many foundational fighter pilot skills learned through non-

[9] Atherton, Kelsey D. "How AI Could Help New Air Force Pilots Avoid Costly Mistakes." *Popular Science,* 15 March 2022. https://www.popsci.com/technology/air-force-artificial-intelligence-pilot-training/.

[10] Christenson, Sig. "Air Force's Pilot Training Next program cuts training time in half ." *San Antonio Express News,* 20 January 2023. https://www.expressnews.com/news/local/article/air-force-pilot-training-method-17728373.php.

missionized training sorties can be done under AI-assisted learning. However, the application of AI in assisting fighter training extends beyond this.

10. The USAF has been employing AI to analyze the vast amount of data recorded by modern fighters, which is typically used for post-mission debriefing purposes and then discarded[11]. Generation 4 and 5 fighters are software-defined, facilitating the collection and analysis of their flight data by an AI. Fighter pilots spend several hours reviewing aircraft recording and reconstructing their flights to identify deficiencies in their performance during post-mission debriefing, a time-consuming process with varying degrees of accuracy. AI can perform the same analysis in a fraction of the time, freeing up pilots to work on other skill development like tactical studies. The USAF has partnered with Crowdbotics, an AI and Machine Learning enterprise, to develop an analytic software for the F-15E that can do that. AI can also amalgamate multiple missions and inform unit standards officers about training deficiency trends within their unit, enabling a more focused unit level training[12]. The Crowdbotics software, for instance, can analyze takeoff and landing performance over a period of time and identify deviations that can escalate into dangerous behavior before they become problematic. This feature is particularly valuable in a single-seat fighter where supervisors rarely review basic flying skills[13].

11. An operational application of such technologies also allows commanders to individually select pilots to assign to specific missions. Modern fighters are multi-roles, but pilots develop skills unevenly; some may excel at air-to-air missions, while other may be better at air-to-ground. By analyzing the vast amount of data collected from individual pilot flying performances, AI can recommend who should fly which type of mission[14].

12. In current Generation 4 and, to a greater extend, on Generation 5 aircrafts, fighter pilot training is largely done using flight simulators. A major drawback of current systems is the lack of realism of computer-generated adversaries that use basic scripted maneuvers. An adversary that could more accurately replicate human-like decision-making would present more beneficial challenge to its training audience, thereby enhancing the value of simulator-based training. Using AI learning techniques such a *behavior cloning*[15], adversary algorithms have already surpassed humans in air-to-air combat[16]. Combined with augmented reality, AI can supplement or even replace the need for live adversary forces in flying events. BAE Systems has developed an

[11] Atherton, Kelsey D. « How AI Could Help New Air Force Pilots Avoid Costly Mistakes ». *Popular Science,* 15 mars 2022. https://www.popsci.com/technology/air-force-artificial-intelligence-pilot-training/.

[12] Oliver, David. "New Age Pilot Training ." *Armada International* 47, nº 2 (April 2023): 24-26.

[13] Atherton, Kelsey D. "How AI Could Help New Air Force Pilots Avoid Costly Mistakes." *Popular Science,* 15 March 2022. https://www.popsci.com/technology/air-force-artificial-intelligence-pilot-training/.

[14] Ibid.

[15] Sandstrom, Viktor, Linus Luotsinen, et Daniel Oskarsson. "Fighter Pilot Behavior Cloning." In *2022 International Conference on Unmanned Aircraft Systems (ICUAS)*, 686-95. Dubrovnik, Croatia: IEEE, 2022. https://doi.org/10.1109/ICUAS54217.2022.9836131.

[16] Sandstrom, Viktor, Linus Luotsinen, et Daniel Oskarsson. "Fighter Pilot Behavior Cloning." In *2022 International Conference on Unmanned Aircraft Systems (ICUAS)*, 686-95. Dubrovnik, Croatia: IEEE, 2022. https://doi.org/10.1109/ICUAS54217.2022.9836131.

augmented reality system that can simulate virtual adversary aircraft[17]. This allows for a better replication of the complex training environment without the need to generate large number of participants. Coupled with an AI "coach", scenarios can be tailored to pilot's training level with a relative ease[18]. BAE's technology has been greatly influenced by the Defense Advanced Research Projects Agency (DARPA) programs which develops autonomous AI capable of fighting one-versus-one "dogfight", against AI and human pilots alike[19], a further advancement in AI technology leading to autonomous, combat capable fighter aircraft. But these technologies are not just for a future aircraft; they can be used in training for fighters like the F-35 as much as for legacy CF-18.

Providing a first steps in harnessing the power of AI in airpower applications

13. AI technology is developing at a rapid pace. The development of AI-controlled aircraft "wingman" is already underway. It is likely that in the near future, even at present, AI algorithms will become the secret weapons of militaries, fostering a level of competition akin to that observed in commercial enterprises for consumer behavior algorithms. However, not all AI system are created equal; their performance largely depends on how they are trained, by experienced programmers[20]. Training an AI to accomplish a task beneficial to humans is a time-consuming process. For instance, DARPA's AI which defeated a human pilot in one-versus-one air combat required ten months of training to reach expert level[21]. While this is impressive compared to the time it takes to train a human to do the same thing, it's worth noting that the AI is only capable of this one task. Therefore, replacing to vast breadth of experience of a human fighter pilot is a multi-year endeavor. The time it takes to train AI significantly varies depending on the learning approach used, called learner policy[22].

14. Following the USAF model, seeking industry partnership is paramount to effectively implement the use of AI in the RCAF. AI enterprises are economically viable because they manage a wide range of projects that use a common baseline, thus offering many development opportunities; having a RCAF team dedicated to developing an AI for a limited range of purpose with not generate an expertise sufficient to compete with adversaries. Industry partnership will best serve the national interest.

15. Developing expertise in this field necessitates research and experimentation. Early adopters of the technology are likely to gain a significant head-start on their rivals. Using AI as a tool to enhance pilot training is a step in the domain that can be achieved with relatively small

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[17] Underwood, Kimberly. "Artificial Intelligence Enables 'Bespoke' Pilot Training." *AFCEA International*, 30 November 2022. https://www.afcea.org/signal-media/defense-operations/artificial-intelligence-enables-bespoke-pilot-training.

[18] Ibid.

[19] "Dans l'Inconnu: Les Robots Tueurs." *Netflix,* 2023. https://www.netflix.com/title/81473681.

[20] Ichaso, Rafael. "Artificial Intelligence – Human Symbiosis in Fighter Aircraft - Joint Air Power Competence Centre." *Journal of the JAPCC*, no. 34 (July 22, 2022). https://www.japcc.org/articles/artificial-intelligence-human-symbiosis-in-fighter-aircraft/.

[21] "Dans l'Inconnu: Les Robots Tueurs." *Netflix,* 2023. https://www.netflix.com/title/81473681.

[22] Sandstrom, Viktor, Linus Luotsinen, et Daniel Oskarsson. "Fighter Pilot Behavior Cloning." In *2022 International Conference on Unmanned Aircraft Systems (ICUAS)*, 686-95. Dubrovnik, Croatia: IEEE, 2022. https://doi.org/10.1109/ICUAS54217.2022.9836131.

investment. This opens the door to further investments in the field, subsequently building the expertise to undertake more complex projects like autonomous systems. It is expected that these AI will be tightly guarded, proprietary secrets; fostering an industry-based national expertise is an important capability to develop, and the payoff in experience will have a synergetic effect across Pan-Domain force development programs.

CONCLUSION

16. AI has many applications, with more yet to be developped, but the RCAF uses very few of them. There's an immediate need to revamp the pilot training system in light of instructor-pilot shortage; AI can assist through AI-assisted learning. Fighter pilot training is becoming more complex and requires more realistic scenario to prepare pilots to the challenges of future battlefields; AI can help create those training conditions. AI, being inherently associated with simulated and augmented reality training, enhances the value of simulated training solutions compared to flying an actual aircraft. This reduces the need for expensive, high-maintenance fighter aircraft flights to achieve the same level of proficiency. AI has the potential to improve the quality of pilot training while simultaneously reducing the time and monetary cost. It is also not a temporary solution; AI system are becoming an integral part of our life and are here to stay, providing no reason to delay implementation of such system.

RECOMMANDATION

17. It is recommended that the RCAF leadership collaborate with research partners and industry to develop AI solutions in the following fields:

a. Utilizing AI to assist Initial Pilot Training candidates in learning basic flying maneuvers through AI-assisted curriculum;

b. Employing AI to analyze post-mission data and provide fighter pilots with performance assessments;

c. Leveraging AI to develop customized, individualized training scenarios for fighter pilots;

d. Applying AI to improve the realism of computer-generated adversaries during simulator training missions;

e. Investigating augmented-reality solutions to enhance live flying missions.

18. Furthermore, it is advised to concentrate research and development resources on AI-assisted flying training in order to gain experience in the field and collaborate with allied nation with developing future AI-enabled capabilities.

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