Proto-flighting in the wild: a creative technologist approach to drone prototyping

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Abstract

The practice of First Person View (FPV) drone flying is not entirely understood. The physics bending agility of the technology and tight coupling of this with a pilot's senses is an emerging field of research into embodied relations and Human Drone Interaction (HDI). The assemblage, integration and tuning of a boutique system of FPV hardware and software that is bound together with open-source firmware in a self-directed mode allows an enormous amount of freedom and application, but also involves tacit knowledge and continuous experimentation that is inextricably bound to processes of prototyping.
The role of a do it yourself (DIY) remote control aviation hobbyist who flies FPV drones is complex and multifunctional. The act of flying these high performance tele-operated robots for recreation is built upon a foundation of specialist craft and technical knowledge across multiple fields that range from materials science to computational systems management. This paper will unpack a creative technologist approach of how a DIY FPV pilot integrates hardware, software and firmware with their drone and generates new experiential knowledge through iterative processes of prototyping across multiple fields. This practice is driven by a desire to perfect a phenomenon known as 'flight feel' that sits outside the normal aims of a staged prototyping scenario and involves a variety of prototyping methods that when combined with modes of sensing and flying in the wild, becomes what could be considered proto-flighting.

Human Drone Interaction; First Person View; Embodiment; Prototyping; Proto-flighting

The development of drone technology has radically impacted warfare, media, research, recreation and industry. It can be understood as a "socio-technical assemblage of the sky and vertical space" (Crampton, 2016, p. 137). Emergent methodological tools combined with new approaches to sensor, power, and control systems of drones offer opportunities to understand the relationship between technology and human. High performance FPV drone technology has quickly evolved into a highly adaptable tool that encompasses elements of making, open-sourced software and technical mastery in which the "human operator is surrounded by the machine, is intimate with the machine, becomes the machine" (Mindell, 2002, p. 63; cited in Garrett & Anderson, 2018, p. 348).

This paper explores a discrete aspect of FPV drone making and tuning processes, and reveals how the relationships between technology, environment and human evolve. It focuses on the embodied experience of fabricating parts and integrating components onto an FPV drone and then the testing of the system by flying at an outdoor location. It interprets how a prototyping ‘in the wild’ method - an agile development process that enables evaluation and rapid evolution in real life situations (Hutchins, 1996) - plays a key role in achieving FPV flight dynamics. This approach contrasts with prototyping in a Lab or synthetic environment as it foregrounds the spaces between technology, human and environment and offers insights into how the innovation of hardware, software and firmware happens simultaneously, developing new experiential knowledge through processes of doing.

The research presented in this paper sits inside a broader PhD research project that seeks to understand the embodied experience of FPV drones.

Situating FPV drone practice

The process of piloting an FPV drone involves a pilot (human), a drone (technology) and airspace (environment). The role of the pilot in flying an FPV drone is complex. In its simplest technical understanding, the pilot controls or operates the technology or machine while responding to a given environment. Mollica (2020) extends this notion and suggests that the role of an FPV pilot is intricate, immersive, and more than tele-operational in nature. He describes the field of FPV drones as one that encompasses many technical literacies, including specialized systems management, data interpretation, environmental navigation, radio theory, electronics, making, coding, tinkering, flying techniques and practices (2020). He presents a sequential treatment of interrelated topics that build understanding and proficiency in the techne of FPV with the aim of mastering a web of complex technical barriers to “become the machine” (Mollica, 2020, p. 11). This concept extends past a simple technical understanding of a hobby practice and recognizes that the role of an FPV pilot is complex and requires the acquisition of knowledge by doing. Garrett & McCosker suggest that in this modality the drone is not “a simple cyclops eye that flies but rather part of a more-than-human sensorial assemblage” (2017, p.16). This type of close physical association between a human and technology is described by Don Ihde as embodiment (1990). In the context of FPV piloting this suggests that when the pilot masters technical literacy and becomes the machine (Mollica, 2020), the drone and the pilot are one. Eriksson et al., identify this relationship or embodiment as a dialogue that requires a kinaesthetic awareness to achieve inter-corporality between human and drone (2019). This intimacy is also described by Jablonowski as a “carefully and constantly established, attuned, and adjusted relation of mediation between the technological infrastructures of remote control and remote sensing and the embodied sensory perceptions and actions of the human user” (2020, p. 345). This builds a position where the FPV pilot is a do-it-yourself (DIY) prosumer who has a deep relationship with their materials. This extended practice of amateur aviation is supported by a host of social media, web, club and print media resources. This understanding and connectedness allow construction of boutique drone assemblages that best suit the pilot and the environment that they operate in.

In one of Jablonowski’s ethnographic interviews the pilot “describes a sensory perception which by far exceeds the objectively transmitted sensor data; he experiences an immediate feeling of synesthetic and kinaesthetic pleasure. The drone becomes a sensory organ of his; due to its mediated coupling with [the] body” (2020, p. 348). In this way, it becomes, what Merleau-Ponty describes as part of his “body schema” (1958). What is not elucidated in these interviews is how the processes of making and integrating the FPV drone operate. These processes are critical to how an FPV drone pilot gauges and evaluates the flight dynamics and 'flight feel' of their system. This complex arrangement of understandings and actions could be understood as what Barad defines as 'intra-action' (1998) where the conditioning between humans and non-humans is one of possibilities. This suggests that a reasonable amount of psychic mobility and out of the box thinking is required to translate bodily and sensory experience into a set of coherent commands and decisions to make pre, real time and post flight adjustments to the FPV drone system that have desired impact. This research paper focuses on understanding the experiential union between pilot and drone by elucidating where the processes of different types of prototyping happens, what some of the key concerns of this activity are and how the experience gained through prototyping affects 'flight feel' to gain a better understanding and articulation of these relationships.

Other research has analysed the learning experience of becoming an FPV drone pilot and how that affects connectedness. Tezza et al., surveyed FPV pilots and describe the mechanical relationship of the hand to the remote controller, flying modes and skills gained (Tezza et al., 2021). However, they did not articulate bodily experiences or mental processes. These research findings specifically address how different FPV flight modes change the relationship the pilot has with the craft, they suggest that "future studies could objectively evaluate how each grip mode impacts human-drone interaction" (Tezza et al., 2021, p. 4). This study shows how currently, the subconscious and bodily interface between FPV drone and pilot are not well catalogued or understood. In addition, they note that there is limited research conducted from the first-person pilot perspective or how the making, doing and culture of the hobby operates. The position of the human in the loop as an emerging area of drone research is also highlighted by Herdel et al., (2022) in their scoping review of domains and applications of drone research in Human Computer Interaction (HCI). This paper will directly address this gap in knowledge by revealing how the development of the practice of FPV drone flying is an amalgam of experiential knowledge and prototyping.

The role of prototyping

Design is an integral component of many disciplines including engineering, education, art, architecture, urban planning, business, computer science, and others. Simon suggests that "everyone designs who devises courses of action aimed at changing existing situations into preferred ones" (Simon, 1988, p. 67). This can be understood as meaning that "design" is to improve the world around us. He goes on to frame how examining human created artefacts, involves a departure from the objective observer that has an independent scientific findings model and introduces the science of the artificial, which has human values and actions embedded in it (Simon, 1988). Design researchers have been active in understanding human drone relationships. One recent project explored the proximity that humans will afford drones. Wojciechowska et al., noted that when the drone was within participants personal space, most felt "that the drone wanted to communicate with them" (2019, p. 179). This approach focused on co-location, proximity, and trajectory with a wide range of surveyed participants. This highlights the role of the drone as a functional object that has agency. In this setting it is an item of technology created for shaping and learning about possible futures. Schön suggests that the use of a prototype intrinsically, helps designers learn about design challenges and the world the prototype operates in (Schön, 1983).

An approach to HDI is presented by La Delfa et al., who created a research project called Drone Chi (2020). They present a quasi-chronological pictorial development of the project that had multiple perspectives embedded in its design process (La Delfa et al., 2020). Drones were investigated as a material for designing soma-aesthetic experiences and produced iterative low fidelity prototypes to drive the research development. They found that participants felt the “intimate correspondence” between themselves and the drone, “feel as one with the system” (La Delfa et al., 2020). This sense of union was created by the careful application of soma design principles and prototype development.

Drone presence and interaction is directly addressed by Eriksson et al., in a different setting (2019). They discuss problems and solutions to performance-based drone interaction. They created a choir composed of drones with loudspeakers as a performative choreography for a commissioned opera. In their research they present a methodology where the interactions of the drone and the choreographer are critical to the design phase an aspect of this process is revealed as an evolutionary software prototyping and that it offered "new forms of engagements, such as first-person felt perspectives" (Eriksson et al., 2019, p.1) as key findings that are folded into the final performance of the Opera.

All of these drone human interaction projects used drones as communication objects and had different prototype development as a critical stage in the research. Notably, they were all located in controlled enclosed environments. Hildebrand departs from this model by doing auto-ethnographic research in the wild. She addresses the notion of drone piloting experience by considering flight operations as ‘auratic’, framing it as a playful act that enables “aerial exploration, creative expression, geographical literacy, and imaginative mobilities in ways that suggest expanding conceptualizations of the aerial gaze” (Hildebrand, 2021, p. 20). This points to a heightened relationship between the pilot and the drone where the participant not only feels what the drone sees, but how the drone is performing in the environment. This binding of sensors and human sensing affords new ways of thinking about tele-operation and tele-presence. Jablonowski argues that “drones’ media-technological apparatus allows for a virtual-somatic feeling of presence in spaces where human bodies cannot (or almost cannot) be and move” (2020, p. 347).

A key commonality that links these design research prototyping approaches and theoretical frameworks that situate drone research is the inherent requirement for humans to unionize with the drone system and that it is in more-than a simple tele-operational modality. The possibilities offered by the transdisciplinary, DIY nature of FPV drone practices and the continuous development cycle that the open-source environment, which is inherent in the design and functionality of the technology, positions the FPV drone system and its human pilot as an innovative unified form of prototype that rapidly changes over time and has its own type of agency when located in the wild.

This paper will show how a creative technologist approach to prototyping and evaluation in the field can extend the exploration of new research fields, such as HDI.

A creative technologist approach

This research used a creative technologist approach to engage with drone technology to generate new understandings of the FPV pilots experience and practices. Creative technology is a relatively new field of study (Connor, 2020). The most commonly understood position recognizes the domain as inherently interdisciplinary and draws from multiple fields such as engineering, computer science, design studies and the arts in terms of creative outputs (Mader & Dertien, 2014). Mader and Eggink suggest a creative technologist approach empowers a researcher “to make use of existing technology in novel combinations - in contrast to developing new technology” (2014, p. 1).

The creative technologist approach to this research is grounded in methods such as tinkering, making, hacking and assembling technology to discover possible integrations (Connor and Sosa, 2018). This is accompanied by the forming of an adaptive reflective narrative that allows for the evolution of artifacts and processes to occur. This research investigated the more than human union afforded by FPV drones where "the interaction becomes a dialogue, a negotiation, between the technologies and humans" (Eriksson et al., 2019, p. 3). In this way “the objects, systems and knowledge are constructs that can be challenged and changed as new thoughts, technologies and approaches arise. The process of continuous creation is characterized by ongoing transformations and reconfigurations” (Connor and Sosa, 2018, p. 3). This interdisciplinary approach significantly deviates from traditional design methods around prototyping towards a refined product or service application. It reflects the continuous dialog and interaction that a non-dualistic design process entails to elucidate the relationship that Jablonowski describes as “synesthetic” or “non-human, multi- and extrasensory” (2020, p. 347). This research has used auto-ethnographic methods to record ‘materially discursive’ (Barad, 1998) intra-actions in the wild by recording and mapping flight logs, reflections in and on action, black box data, photography, video and audio. Cycles of action research were interwoven into the practice to drive the tinkering, making, hacking and assemblage components of the research. This hybridized approach as auto-technography, exposed an agile iterative prototyping method as a core component of FPV drone behaviours. It aims to generate new knowledge about the position of the human in the loop in the field of HDI that has been highlighted as being absent by other researchers (Herdel et al., 2022).

Experiencing FPV Fundamentals

This section will describe different types of prototyping that emerged during the research practice of flying FPV drones which enabled the creation of practical knowledge and supported empirical research. The examples involve hardware, software and firmware and were simultaneously developed through iterative cycles of prototyping using the same FPV drone. These activities ranged from materials experimentation and prototyping to open-source software development strategies, such as evolutionary and incremental prototyping development processes.

Location of practice

This research paper focuses on the fabrication and then flying of an FPV drone within a forest environment with the aim of exploring and experiencing it from a new perspective. It also investigates how 'flight feel' is developed. This environment is very complex, with a high occurrence of and extreme proximity to obstacles. For the purposes of this research, the selected flying location was considered a configurement space that was 300 meters x 300 meters x 20 meters in volume. These dimensions were dictated by the radio and video link between the pilot and the drone (refer to figure 1).

Figure 1: (Cleveland, 2022) Flying practice in the forest [photograph]

The practice was carried out daily over a three-month period. A real-world flying location was selected as it would be a challenging extension of practice for the lead author, who has been researching making and flying drones since 2016. It is also in line with New Zealand Civil Aviation Authority regulations (CAA 101 pt.1) that govern the use of drones in the national airspace. The following flight operations were conducted in a privately owned mature conifer forest, in the mode of a 'shielded operation'. Locating the research in a pseudo-laboratory allowed for a real physical environment where the 'doing' component of the practice would not have manmade limits such as volume of space, timetabling and logistics. This approach foregrounded the dynamic nature of the forest environment and atmospheric conditions. This combined with the technology and the human into an amalgam that afforded unified decision making and supported learning about unknowns. This was experienced in multiple ways. Notably, the building of mental flight maps whilst operating in the space became a navigational practice that entailed connecting discovered and possible flight paths together to prototype changes in the technical system and as the practice expanded, increase human generated variables such as risk. Another key benefit to this location was that it allowed the lead researcher aloneness, a scenario that is not always viable in a lab setting and is in line with conducting auto-ethnographic research that had components of audio and video as recorded data.

Hardware

The hardware selection for this project consisted of hobbyist grade componentry. The initial making and configuration of the drone was carried out in an engineering makerspace at Auckland University of Technology. Hacking, tinkering, maintenance and prototyping in the wild was also carried out on location in the forest. The air frame (drone body) selected for this purpose was a kit set consisting of machined carbon fibre plates connected by aluminium stand-offs and fastened together by M3 bolts. It has the key feature of ducts that surround its four propellors. In this instance, the ducts and ancillary parts were 3D printed by the lead author. The novel use case for this drone demanded iterative materials experimentation and rapid prototyping to fabricate ducts that maintained the tolerances required to produce efficient thrust and be robust enough to withstand an amount of contact with flora in the forest environment. The duct iterations started with using a polylactic acid thermoplastic (PLA) material common in rapid prototyping with 3D printers. Multiple adjustments and refinements were made to the stereolithography file (STL) as the prototyping process unfolded to increase the structural integrity of the ducts at the contact points with the frame. After multiple iterations and flight testing of these ducts, a functional accurate prototype was fabricated out of nylon using selective laser sintering (SLS), an industrial 3D printing process (refer to figure 2).

Figure 2: (Cleveland, 2022) SLS 3-D printed componentry [photograph]

In tandem with this iterative prototyping was the selection of the type and sizing of the propellors, which had to be cut down to very specific tolerances, to suit the critical dimensions of the ducts. The propellor selection moved from high pitch tri blades to low pitched octo blades. The shape and mechanical properties of the blades had a big impact on the flight dynamics of the drone. A jig was fabricated and fitted to a rotary tool that allowed replication and precision when cutting the blades to length and many iterations and trials of blades with different properties such as aerofoil, chord and pitch distribution were prototyped. It was not possible to simply generate data from a static thrust calculator to simulate and predict the duct, blade and motor combination to forecast performance. The amputation of the end of the blades and duct configuration disrupted any attempt at using a software-based calculator and produced highly variable, unusable results. Evaluation and decisions about the effectiveness of each blade type was driven by what soma designers describe as "first-person felt perspectives" (Eriksson et al., 2019). Achieving maximum performance from the ducts, propellors and motor combination enabled the drone to be more efficient with each iteration. However, the results achieved were such that during the practice a new soft material, Thermoplastic Polyurethane (TPU), that was more tolerant to contact with flora at velocity was 3D printed and introduced. This became necessary as the kinaesthetic awareness of the pilot and risk taking with the drone in the environment increased. This physical prototyping and holistic negotiations with the drone and the environment produced a 'flight feel' that was bright, nimble and robust. The role of iterative prototyping and iterative material experimentation in tandem during this process was crucial in developing the drone (refer to figure 3).

Figure 3: (Cleveland, 2022) TPU 3-D printed componentry fitted on the drone with cut down propellors [photograph]

Software

Software is a continuous site of development for FPV pilots. The open-source network of developers and supporting social media resources are constantly bringing to production software hacks and applications that can be integrated into the FPV drone system. Releases of this boutique software are often deposited on the open source Github platform and supported by a temporary community that evolves around the project. Real-time feedback from the developers and community is then available for problem-solving and testing in an agile development mode. An example of this was the hacking of the digital DJI air unit and FPV goggles, used by the lead researcher on this project, to provide an external stream of the digital video feed coming from the drone onto a secondary platform. The code was first made available to the FPV drone community as a linux image hosted on a Raspberry Pi and involved iterative cycles of trial and error to install and configure before becoming stable enough to use. This evolutionary software prototyping process in its initial stages was functional but proved cumbersome to use in the field due to the amount of apparatus required to support it. A refinement of this application became available from the open-source developers in the form of a software developers' kit (SDK app) that could be run on an android device. This evolutionary prototyping approach from the open-source developers resolved the issue of portability and allowed this research to stream and record video off board from the DJI googles and air unit platform, in real time. An unexpected advantage of this was that playback from flights was available in the wild which allowed for reflection in and on action and highlighted the performance of the drone whilst prototyping the various duct and propellor configurations. This was displayed on a flat screen that could be analysed and played back at different speeds. What emerged from this new ability was a sense of how the different ducts affected the flight dynamics of the drone with regard to slowing it down. The form factor and materials of the ducts had a very big impact on the performance of the drone as the ducts acted as an air brake which was in many respects more useful for controlling the drone in the forest environment than optimising thrust and power which was the initial aim of the process. The amalgamation of materials prototyping, and open-source software prototyping - which can be described as an incremental prototyping process - allowed the researcher new opportunities to explore space in a more than tele-operation mode guided by “first-person felt perspectives “(La Delfa et al., 2020).

Firmware

Interlaced with all parts of the drone system is the firmware that runs the flight controller. Firmware can generally be considered embedded code that provides basic instructions that sets the behaviours of the hardware and allows communication with other software running on a device.

This research used the open-source Betaflight firmware hosted on a specialised hobbyist flight controller board. This firmware comes with a host of companion applications and a very powerful configurator that allows adjustment of every variable in the system. A fundamental feature of the Betaflight soft and firmware architecture is a focus on flight dynamics and performance which is managed through a Graphical User Interface (GUI) called Betaflight Configurator. This interface, which is achieved via a USB connection to the flight controller board, allows complete control and tuning of the low order flight controller settings as well as management of the peripheral devices connected to it. This tool is available on multiple platforms (such as a laptop) and can be used on location in the wild.

In essence, the GUI is how an FPV pilot talks with their drone and is a capacity that Mollica suggests is a vital form of technical mastery (2020). This software tool, we suggest, allows what Barad identifies as “material discursiveness” (1998) by giving the FPV pilot an ability to drill down into the exact behaviours of both the human and technology sculpted for a particular environment. This is achieved by the GUI affording a granular level of detail and control of any part of the FPV drone system without concern for any other part of it. Reflection on the performance of the drone is also available through a process of black box recording and review and produces a flow of data that can be analysed using a companion open-source application, Betaflight Black box log viewer. This is an interactive viewer which allows the pilot to closely analyse actions and responses of the system to any given input, post flight. This can then be acted upon by changing firmware settings or addressing any highlighted hardware issues. This capability is a major departure from closed source consumer drone systems that limit access to individual settings by providing a curated user experience. This data stream is also an important component in building maps of experience (refer to figure 4), as it can be used to visualise data from a flight when rendered with video footage captured from the drone. This can then be combined with other data streams such as global positioning system (GPS) and auto-ethnographic footage of the pilot to present a new perspective of the experience of flying an FPV drone in the forest where the technology, the human and the environment have agency.

Figure 4: (Cleveland, 2022) Map of experience [screenshot]

From Prototyping to Proto-flighting

The attunement modality between the technology, human and environment is in practice a step change model that begins with technical process and techne, as craft or technique, being paramount.

This standard FPV pilot behaviour/practice began with flashing the latest version of the Betaflight firmware onto the flight controller board and completing a digital and physical integration of the parts of the drone system. This was validated by doing short test flights. The next steps involved computational considerations, such as the rate that the flight controller achieves a desired input from the handheld remote controller (RC) highlighted by (Tezza et al., 2021). Then attention to the tuning of more complex relationships such as radio link data packet management and filtering. Each of these integral intra-actions built an objective understanding of the FPV drone assemblage and was a starting point for a continuum of conversation between the technology, the human and the environment centred around the firmware. As the system stabilised and became suitably predictable, the kinaesthetic experience changed from one of newness and uncertainty to one of sympathy and resonance. The embodied perceptions of flight transformed into a simultaneous experience of rhythmic velocity and confidence in taking risk, uninhibited by the minutiae of command-and-control and was sensed as a flow of colour and space.

These glimpses of the possibilities of flying in the environment were due to tactical deconfliction of the drone system and its pilot and an emerging comfort with the environment. This type of sensing was initially for short bursts of time and indicated that a new phase of inter-corporal engagement was emerging. This was a product of human and technology seamlessly coming into union in an environment that, over time, became more accommodating. An example of this was the experience of being lost whilst flying in the forest and having to continue flying whilst nervously considering battery consumption. A sudden shift into listening intently for the drone and recognition of a specific pool of light around a fallen tree re-established positionality and relationship between the drone and the pilot. This afforded a successful physical reunion between the two but also created synesthetic experiences such as uncontrollable knee shaking and butterflies in the stomach. During the initial stages of this research these types of experiences in the environment would often end in crashing and the pilot having to walk around the forest environment to recover the drone. This also fostered a new intimacy with the environment as the maps of experience extended to include different layers such as canopy, sub canopy, scrub, herbaceous and aquatic layers of the forest environment.

At the end of each test flight consideration of moments in time during the flight that inhibited or accelerated the experience were translated into an adjustment or reconfiguration of the system via the GUI until a harmonised arrangement was reached. The researcher also recorded the feel of the flight as notes in the form of flight logs and reflections. These reflections on action also took in how other inhabitants of the forest negotiated the complex environment and commented on how successful emulating them with the FPV drone was. An example of this is how the New Zealand Fantail, a small insectivorous native bird that is a constant companion in the forest, darts about in the sub canopy, with rapid direction and elevation changes. This was a very different flight path strategy that resulted in many contacts with the flora and a focus on fighting crashes when they were happening so as to fly through the incident rather than give up and disarm the drone when entanglements or contact happened. By continuous adjustment of the system and adaptive practice as a pilot, flight pathways which were an exciting procession of near misses emerged. This opened the range of possible flight operations up to include small waterways and near to ground shrub terrain and allowed a type of diving and swooping from the canopy into ground level biota. This development produced a high energy feeling of free-flowing flight in the forest and gave new insights into how the experience of FPV fundamentals can be evolved into new maps of experience to suit what would normally be considered a hostile aviation environment.

The experience of prototyping in the wild highlighted an inflection point that emerged during test flying the FPV drone. This was when technical concerns diminished and an all-encompassing involvement in the moment of flight was amplified. The new modality could be considered proto-flighting where optimising a prototype transforms into an optimal experience. This objective unpacking of what Jablonowski terms as ‘more than tele-operational' (2020) is anchored in the perceived feltness of the changes made in the flight dynamics of the FPV drone, new spatial awareness and making things happen. This highlights how a creative technologist approach using different prototyping strategies and auto-ethnographic practices can combine to create new experiential knowledge in the FPV drone space.

Conclusion

This paper unpacks how a creative technologist approach, weaving multiple prototyping strategies together, enables the creation of new understandings and supports auto-ethnographic research in the area of HDI. The foregrounding of the lived experiences of how an FPV pilot develops with the technology in the wild is one that involves multiple forms of prototyping including rapid, iterative, incremental and evolutionary prototyping strategies. The uncovering of air braking as an important flight dynamic in a forest environment was made possible by amalgamating experiential knowledge and different types of prototyping. This was carried out across multiple domains simultaneously, that then transformed into the felt experience and method of proto-flighting. The building of auto-ethnographically recorded and reflected upon data layers combined with embedded technological data tracking introduces opportunities for new understandings and experiential knowledge in the form of maps of experience. This approach of layering captured video and audio data, black box logs, flight logs and reflections can give insights into the dynamics and embodied experience of flying FPV drones. This research begins to address a gap in knowledge about the 'human in loop' highlighted by Herdel et al., (2022) by exploring and articulating practices and behaviours of an FPV pilot in a real-world scenario that can be understood as proto-flighting in the wild.

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