Taking That Perfect Aerial Photo: A Synopsis of Interactions for Drone-based Aerial Photography and Video

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ABSTRACT

Personal drones are more and more present in our lives and acting as "flying cameras" is one of their most prominent applications. In this work, we conduct a synopsis of the scientific literature on human-drone interaction to identify system functions and corresponding commands for controlling drone-based aerial photography and video, from which we compile a dictionary of interactions. We also discuss opportunities for more research at the intersection of drone computing, augmented vision, and personal photography.

CCS CONCEPTS

• Human-centered computing → User interface design; **• Applied computing → Avionics**.

KEYWORDS

Aerial photography, video, drones, interactions, gesture input

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Figure 1: What input modalities are convenient and effective for users to control drone video cameras for aerial photography? The low-cost Parrot Mambo Fly personal drone is exemplified in this figure and discussed in the text.

1 INTRODUCTION

Applications of drone computing cover a diverse range of industries and fields, from intelligent transportation systems [3] to live inspection in constructions [15], emergency situations [45], and delivery services [39], to name just a few. On a distinct level of scale and user experience, personal drones, readily accessible and affordable, deliver functionalities that range from user assistance in taking selfies [10] to video conferencing [22], social companionship [24], haptic feedback in VR [40], and navigation in Mixed Reality [20].

One particular application of personal drones is *aerial photography and video* [11,16,23], where new vantage points are opened to professional and novice photographers alike to capture life's moments. Even small and low-cost drones well under $100, such as the Parrot Mambo Fly illustrated in Figure 1, feature first-person view (FPV) and live video streaming to a connected device. Interactions with drones to take photographs and record videos from aerial perspectives are usually implemented with flypads or apps on smartphones and smartwatches.[1] However, for a novice user operating Mambo Fly, the experience of taking an aerial photo may be affected by how difficult it is to control the aerial perspective with the flypad or the touch UI. For a professional photographer employing a more advanced drone model,[2] ineffective interactions may have direct consequences on the process of taking an artistic photograph. In contrast to these conventional input devices, prior work has examined other input modalities to interact with drones, such as gestures [8,9,13,36], but aerial photography and video have been rather neglected compared to the emphasis that has been put on controlling drones in flight, e.g., take off, land, fly sideways, etc. [1,7,8,13,30]. Consequently, more work is welcome to design meaningful interactions for drone-based aerial photography.

1.1 Context and Contributions

According to Funk's [14] overview of flying user interfaces, the most prominent uses of drones in Human-Computer Interaction research have been flying cameras, flying screens and projectors,

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[1]For instance, the Drone Director app for DJI Drones is available for iPhone, iPad, and Apple Watch, https://apps.apple.com/us/app/id1144121416
[2]Unlike the low-cost Mambo Fly drone with a 720HD camera, the Parrot ANAFI models offer 4K UHD 3840×2160 at 30 fps.

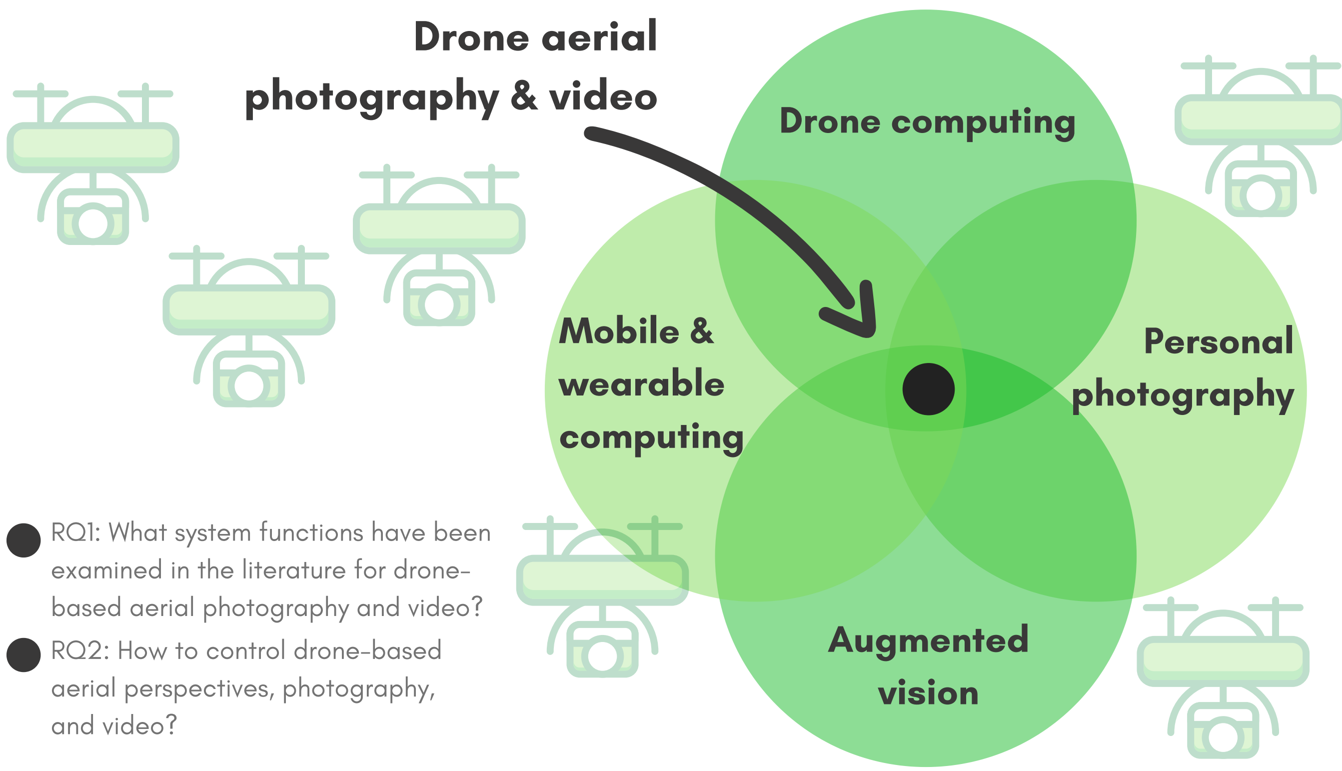

Figure 2: The intersection among drone computing, mobile and wearable computing, augmented vision, and personal photography specifies the scope of investigation of our work.

flying tactile props, and providing in-air companionship. In this work, we focus on the first category and address human-drone interaction design to control aerial photography and video by targeting a specific category of drone users—photographers, professionals and hobbyists alike—less voiced in the IMX community. Figure 2 shows the context in which we position our work, as follows:

- Our scope of investigation relates primarily to *drone computing* regarding live video streaming, high-definition photography [38], and the privacy of bystanders [3,44].
- We connect to *mobile and wearable computing* for interaction techniques using personal devices, such as smartphones—the most ubiquitous type of devices, alongside remote controllers, to interact with personal drones. Interaction techniques based on voice [28] and gesture input [8] to control drones using such devices fall at the intersection with *drone computing* in our Venn diagram.
- *Augmented vision*, since the majority of drones with embedded cameras feature FPV, enabling users to immerse in the aerial perspective of the flying drone [29].
- *Personal photography*, enabled by smartphones [25], tablets [6], 360-degree cameras [21], smartglasses [5], and other devices, intersects the previous categories over drone photography.

In this context, we conduct a synopsis of the scientific literature on human-drone interaction, from which we extract system functions and commands for drone photography and video, and compile a dictionary of interactions. We also present the perspective of three professionals that use drones as part of their jobs, and reflect on opportunities for more research on drone photography and video.

2 METHOD

We conducted a *synopsis* of the scientific literature to identify relevant papers on human-drone interaction addressing drone photography and controlling the video camera mounted on drones. Unlike other types of literature surveys, such as systematic literature reviews, state-of-the-art reviews, or meta-analyses [18], we see synopses as *rapid* and *systematized*,[3] useful to quickly discover relevant information about a specific topic; see [4] for an example. To this end, we ran the following query:

```
"query": Title: ((drone*) AND (input OR interaction*
OR video* OR photo*))
"filter": NOT VirtualContent: true
```

in the ACM Guide to Computing Literature.[4] We preferred this database since it incorporates references from many publishers: ACM, Springer-Verlag, IEEE Press, Elsevier, MIT Press, and others. Running the above query on the abstracts of the papers indexed in the ACM resulted in a total number of 77 references. We removed references not relevant to our scope, such as papers not discussing

[3]According to Grant *et al.* [18], a *rapid review* employs systematic review methods, but the completeness of searching is determined by time constraints; a *systematized review* includes elements of systematic reviews, but does not always include comprehensive searching (p. 95).

[4]A total of 2,892,573 records on December 18, 2020; https://libraries.acm.org/digital-library/acm-guide-to-computing-literature.

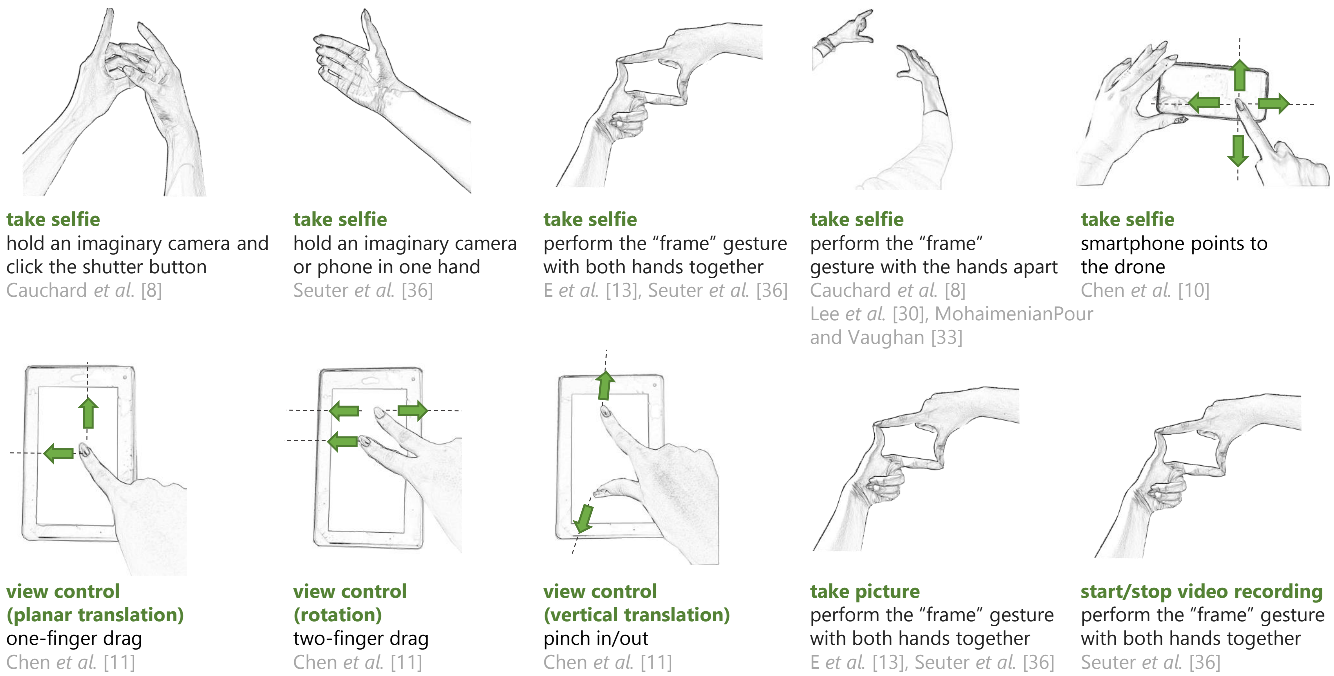

Figure 3: A dictionary of interactions with system functions and commands for drone-based aerial photography and video.

interactions with drones and papers not addressing drone photography or video, according to the following eligibility criteria:

- EC_1: The work is peer-reviewed, available in full text, written in English, and about drones. This criterion filtered out papers for which the word "drone" was mentioned in the abstract for other reasons.
- EC_2: The work is about interactions between humans and drones. Following this criterion, we excluded papers focusing solely on drone technology, such as streaming high-definition video [38] without discussing interactions and papers not addressing human users, e.g., dogs interacting with drones in the area of animal-computer interaction [46].
- EC_3: The work enumerates, explores, discusses, implements, or evaluates system functions for controlling the video camera of the drone. We thus excluded papers exploring interactions with drones for other purposes or application goals, such as controlling the drone in flight mode [35].

After screening the 77 references according to these eligibility criteria, we identified 10 papers that discussed, among others, controlling of the drone video camera [1,7–11,13,30,33,36]. It is noteworthy that, except Chen *et al.*'s [11] work on view manipulation for drone photography and Chen *et al.*'s [10] direct pointing interaction technique for selfie drones,[5] none of the other works identified by our query had photography and/or video as their main scope of investigation for human-drone interaction.

[5]Both works published as posters.

3 RESULTS

We analyzed the ten eligible papers according to the two research questions (RQs) from Figure 2.

Regarding RQ_1, we found that the most frequently implemented system functions for drone video cameras have been taking photos [7,8,13,33,36] and selfies [1,8–10,13,30,36], while commands for recording videos have been addressed to a less extent [7,36]. We identified six types of system functions relevant to our scope: (1) take selfie, (2) take picture, (3) take picture of a specified object, (4,5) start/stop video recording, and (6) stream video from the drone.

Regarding RQ_2, mid-air gestures [1,7,8,13,30,33,36], voice commands [1,7,8,13], direct pointing and touch input on mobile devices [10,11] have been the main modalities in the scientific literature to control drone-based aerial photography and video, complementing conventional flypads and remote controllers.[6] Figure 3 illustrates a dictionary of interactions representing associations between system functions and commands extracted from the papers examined in our survey. For example, taking a picture can be performed with the "frame" gesture with both hands together [13,36] or apart [8,30,33], and taking a selfie by holding an imaginary camera and clicking the shutter button [8]. Some papers examined variations of the "take picture" function by instructing the drone to point at specified objects, such as a tree [13] or a bicycle [36], or by specifying the number of pictures to take and the time interval between consecutive photos [7]. In the case of E *et al.*'s [13] end-user elicitation study, pointing at the target to photograph it was observed in participants' behavior before making the "frame"

[6]For example, pressing the R1 button on the flypad of the Parrot Mambo Fly drone from Figure 1 takes a picture; see https://support.parrot.com/us/support/products/mambo-fpv/taking-photos-mambo-fpv.

gesture. Two papers used mobile devices: Chen *et al.* [11] proposed touch and multitouch gesture input on a tablet for controlling the aerial perspective of the drone, e.g., a two-finger drag rotates the view, and Chen *et al.* [10] proposed direct pointing for selfie drones.

Not all of the papers from our survey described the commands to control drone photography and video. Some of the papers [1,8,13] analyzed the commands proposed during end-user elicitation studies as a group and reported the level of consensus among participants' preferences. Therefore, our dictionary only includes those interactions for which commands were explicitly presented in the corresponding papers. For example, Cauchard *et al.* [8] reported users' preferences for gesture and voice commands to take a selfie in the form of agreement scores [43]. Their results showed agreement of .37 (on the unit scale) for gestures and .63 for voice commands. Abtahi *et al.* [1] reported similar results in their "drone near me" study using agreement rates [42]: .31 agreement for gestures, .55 for voice, and .69 for touch input and safe-to-touch drones (with frames installed around propellers). For unsafe drones, however, Abtahi *et al.* [1] reported .42 agreement rate for gestures and 1.0 (perfect agreement) for voice commands.[7] And E *et al.* [13] found similar results in their multi-cultural elicitation study by employing agreement rates [41]: .39 and .30 level of agreement for gestures proposed by participants from China and USA. However, cultural disagreement was revealed for voice commands with .33 and .60 agreement rates, respectively. In the system designed by Cacace *et al.* [7], the user verbally instructs the drone to take a picture, start and stop video recording, and stream video. Examples of voice commands are not presented, but a reference is provided to a large-vocabulary continuous speech recognition engine.

To complement these findings, we conducted informal interviews with three professional drone users. Two of them (both male, 40 and 24 years old) had nine and four years, respectively, of experience with drone aerial photography. The third user (male, 46 years old) had sixteen years of experience with drones for ground penetrating radar [12] that, although different in goal compared to drone-based photography, employs imaging sensors mounted on the drone. The interviewees expressed their preferences for gesture and voice commands to control the functionality of the sensors from their drones. However, mid-air gesture control of the drone in flight mode was perceived less effective compared to using a flypad, according to their practical experience. Also, simple finger movements and touch input on the drone's flypad were considered faster and less demanding compared to hand and arm gestures.

4 LIMITATIONS AND FUTURE WORK

Synopses of the scientific literature are, by their nature, limited in depth and breadth. By running our query in other electronic databases, such as IEEE Xplore, SpringerLink, and Scopus, other relevant papers are likely to be identified. Moreover, for other types of interactions with drones, we refer readers to other surveys, such as Mirri *et al.*'s [32] discussion of challenges in human-drone interaction and Obaid *et al.*'s [34] survey of domestic drones.

[7]The voice commands, however, are not explicitly mentioned in their paper. However, a previous study [8] found that almost all of the participants used the word "picture" when proposing voice commands to take selfies and photos using a drone. Also, in the study of E *et al.* [13], participants from two different cultures, Chinese and USA, frequently spoke the word "picture" to effect the "take a picture" function.

Based on our findings, we highlight two opportunities for future work on human-drone interaction for aerial photography and video at the intersection of the areas illustrated in Figure 2:

(1) Explore diverse input modalities for controlling drone aerial photography and video. Examples include modalities made available by emerging wearables, such as smart rings [17], but also multimodal input, such as combined gesture and speech for finer control while taking photographs. Other drone application areas have considered specific input modalities, including brain-computer interfaces [26], emotion recognition [31], and somaesthetic interactions [27], which could also be examined in the context of the artistic process of taking photographs and filmmaking.
(2) Integrate aerial photography and video with other applications of personal video cameras [5], such as lifelogging [19] and life abstraction [2], where wearable cameras passively record their users' lives. Integrating drone video with such applications, beyond "follow-me" functionality, could enable new opportunities for drone-powered lifelogging as well as for lifelogging multiple, distinct perspectives of the user's life events. Moreover, integrating drone aerial photography and video with other consumer video devices, such as smart cameras [37], may be equally interesting to explore.

We hope that our preliminary results of the little explored area of interactions with drones for aerial photography and video will foster more work towards more engaging experiences for photographers.

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