Playing with Drones:

Towards understanding the design of drone-based pervasive play

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Human-Drone Interaction is a fast-growing subset of the field of Human-Computer Interaction as drones enable novel and interesting interactions in 3D space as they can be regarded as pixels in physical space. We examine the intersection of drones and play and explore how drones can facilitate playful bodily experiences by pervading the physical space. We focus on “Paida” play to build explorative play experiences that pervade the player’s physical environment. This work resulted in three play experiences built around simple interaction methods, in addition to observations from our design process, and three design strategies; drone-based play lends itself to collaborative play, such play benefits from simple designs, and designers benefit from designing for multiple players. From these design strategies, we set a starting point for designing novel, pervasive, and playful interactions whilst regarding drones as pixels in the physical space.

CCS CONCEPTS • Human-centered computing ~ Human computer interaction (HCI) ~ Interaction devices

Additional Keywords and Phrases: Human-drone interaction, pervasive games, drones, play

1 INTRODUCTION

Human-Drone Interaction (HDI) is becoming an increasingly prevalent topic within Human-Computer Interaction [14, 23]. This growing interest is seen within the CHI community with HDI being a full session in both the ‘19 and ‘20 CHI conferences [2, 11, 12]. This project demonstrates how drones can be used to create engaging pervasive play [13] and set a starting point for designing play using drones. With drones becoming smaller and cheaper [16] it becomes possible to regard them as physical pixels that can be placed within a 3D space in the real world. Such pixels can also provide feedback through attached LEDs, to incorporate a wide range of feedback individual to each pixel. This allows for multiple sources of feedback pervading the physical space the player inhibits. We believe that the use of physical pixels can potentially allow for novel and playful experiences, which we discuss next. To justify our selection of drones as a medium for game delivery, we first compare it to other popular current media for digital game delivery: Virtual Reality (VR) and Digital Pixels.

1.1 Comparing media for game delivery

The first characteristic (Table 1) relates to the social aspect of play, and whether the interactions of the user are clearly visible to third parties such as bystanders. For Virtual Reality, it is possible to see the movements of the user, however, the virtual environment is only visible if the headset is linked to a secondary display. Digital pixels face much the same problem, where the viewer is required to have the same viewing angle as the user to view a display. Physical pixels present a different situation, where the interactions of the user and drones are easily visible. These physical pixels also do not require a controller, as the drones may be able to sense objects and distances from it, meaning that a third party may join in the game alongside the user, which we detail later.

Table 1: Comparison of different media for digital game delivery

CHARACTERISTIC	PHYSICAL PIXELS	VIRTUAL REALITY	DIGITAL PIXELS (SCREEN)
INTERACTIONS VISIBLE TO BYSTANDERS	Yes	No	Yes, if screen is visible
GAME FIXED TO LOCATION	No	Yes	Yes
FEEDBACK	Spatial, Touch, Sound, Sight	Spatial, Touch (Vibration), Sound, Sight	Touch (Vibration), Sound, Sight

Similarly, physical pixels do not always require a specific environment. This contrasts with VR, which currently typically requires either external lighthouse sensors, and digital pixels, which require peripherals such as a power source and a stand for a screen. We note that phones, which are mobile, can also contain game content, however, their location in space is currently only crudely sensed.

Finally, each of the media stimulate a different combination of the users' senses. All support sound, however, regarding the users' sense of sight, depth is only simulated on screens, whereas 3D is available in VR. Both VR and physical pixels support spatial stimulation, however, VR may not always support interactions behind the user, as this may block line of sight to the external sensor.

1.2 Play

As shown in the previous section, drones offer several unique characteristics to play, however, to identify the type of play we would like to facilitate, we follow the model by Caillios [8]. His definition of "Paida" encompasses "wild, free-form, improvisational play", while its counterpart "Ludus" is "rule-bound, regulated, and formalised play" [8]. Currently, there exists quite some research into "Ludus" drone play, for example racing drones [14, 15], gamified law enforcement [10], and sports [3]. This "Ludus" play investigates how drones can be interacted with in a rigid structure, often as a tool of the play, with the drone having little autonomy and the user typically having complete control over the system. Due to the wealth of work into "Ludus" drone play, we choose to focus on "Paida" play. We feel this ties in well with the aspects of game delivery that we identified in the previous section. We believe that drones being not tied to one location allows play to be more "improvisational" and "free-form", with bystander interactions potentially generating more "wild" play, inspired by the Paida definition.

1.3 Linking pervasive play and drones

Pervasive games aim to "pervade" the user's everyday environment, and "be played anytime, anywhere, and with anybody" [13]. We believe that physical pixels lend themselves to pervasive games due to the increase of senses stimulated and increased physical presence when compared to other media. For example, a drone is able to act within an existing space, including items like furniture, and easily move between such spaces. In addition, the innately social aspect of drones, such as viewers seeing all details of the user's interaction, lend themselves to the "[play] with anybody" aspect of pervasive games.

Furthermore, designing the drones to be autonomous would support the "wild" property, as the user may not be able to predict how the drone will react. As alluded to earlier, developing this "wild" property may encourage users to "improvise" in reaction.

If drones are to be autonomous, the user would need to find other methods to interact with the drone, as a controller would remove the drone's autonomy. Autonomous drones allow for greater haptic feedback through this removal of a controller [9] if interactions are to occur between the user and the drone.

In this work, we are answering the previously mentioned call [2, 4] for more research in the area of "Paida" play [8], ultimately deepening our understanding of drones and play.

1.4 Benefit and Contribution

We contribute design observations from designing drone-based pervasive play and three design strategies for facilitating such play. The research conducted within this paper is particularly pertinent to designers of HDI, such as drone game designers, or those involved with designing playful interactions for which drones have potential to be utilised within.

2 RELATED WORK

We draw knowledge from prior work from the areas of drones as tangible objects, autonomous interactive drones, and anthropomorphising drones through movement. Within this section we unpack how these works influenced the design of our work.

2.1 Drones as tangible objects

While some work has investigated HDI with controllers [10, 14, 15] to create an increasingly pervasive environment with the drone operating near the user, we draw on the knowledge of how drones can be designed as "tangible objects".

On the subject of how to interact with the drone, a recent study investigated the impact of collocated HDI with gestures replacing a controller between the user and drone. This work confirmed that the "natural" method of interaction positively impacted the social aspects of the interaction [18]. This was incorporated into our design by adopting a gesture-based interaction system as opposed to controller-based.

2.2 Autonomous drones

Recent studies with autonomous drones outline design implications. This includes designing for simplicity and encourage deliberation of actions by the user [2]. The theme of slow movement has been reinforced in other studies [3], such as testing a drone's capabilities in boxing against a human. This study found that while engaging with drones in exercise is enjoyable, present day drones are not suitable for fast and precise movement. Therefore, within the confines of current technology, slow movement is seen as key within HDI design. We transferred this into our design by focusing on slow movement and avoiding complex rule sets for the games.

Within both previous works, the drone has had some level of close proximity to the user. This has also been investigated in studies surrounding drone's use as a running guide [1, 4]. From this work it was suggested that the drone sharing close personal space with the user is an effective tactic for supporting the movement of the user. This was incorporated into our design by emphasising the linking of the movement of the drone to the movement of the user.

2.3 Anthropomorphising drones through movement

Recent work has investigated methods to increase the positive experiences of users when interacting with drones through increased animacy of the drones. A recent study identified that "guiding" the drone can lead to users assigning qualities to it similar to the qualities of a puppy, while a lack of an opportunity to guide the drone can lead to more negatively assigned qualities [6]. Our design incorporated this by providing opportunities for the user to “guide” the drone.

Reinforcing this, a recent paper investigated the effect of HDI through gestures. This work found interacting through gestures resulted in the experience being correlated to interacting with a person or a pet [17]. We incorporated this knowledge from both works into our design in situations where we required the drone to emulate an animate creature.

2.4 Research Question

This prior work led us to the research question of: How do we design pervasive games using drones?

3 METHOD

This research was conducted through iterative development, following the research through design approach [19], where the primary researcher is a user of the system, to record and build on feedback. We approached this research through design by creating multiple sequential prototypes, building on feedback of other researchers, experts, and non-experts.

We put forward three prototypes of drone-based pervasive play. These prototypes were developed using the iterative agile methodology [21], as is typical of software development.

3.1 Prototype Design

To design these three prototypes, the movements, and actions with which the player could interact with the drones, was both brain-stormed and body-stormed [22]. From this, the key movements of ‘push’ and ‘pull’ (Fig. 1) were established, which formed the basis of play.

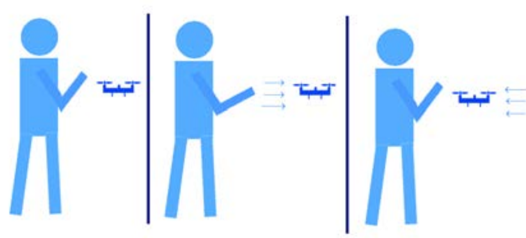

Figure 1. Demonstration of push and pull concepts of interacting with the drone.

Once the core concepts of the play were established, different play variants were explored using Wizard of Oz testing [23]. This involved stand-ins for the drones to check how the play occurred, whilst following a flow-chart of actions. Feedback for this stage of testing was obtained from a 1-hour weekly meeting with an experienced HDI researcher. This also included a 10-minute demonstration to a group of 5 fellow researchers within the broader HCI field, including the aforementioned HDI researcher, 1 fellow female researcher with junior experience in HCI, 1 male researcher with experience in design and participation in past HDI works, 1 male researcher currently finishing his PhD in HCI work, and finally, 1 female researcher with experience in edible HCI, and experience as a former professional game designer.

Following the feedback on these early examples, we moved to concrete outlines of how the play would occur through the generation of pseudocode for each of the three prototypes.

3.2 Prototype Development

Following establishment of pseudocode for each prototype, the translation into code began. Each prototype was developed for 2 weeks, during which the researcher would record a total of 15 minutes of video footage, and a non-expert play tester would provide feedback on the prototypes after experimenting with it for 30 minutes twice each week.

4 DESIGN

The drones were Crazyflie 2.1 micro-quadcopters (approximately 10 cm diameter). Four Crazyflies were developed, two with the Flow 2.1 and Multi-ranger decks attached, one with the Buzzer and Flow deck attached, and one with the Buzzer and LED deck attached. The Flow 2.1 deck allows for stable drone flight and position estimation relative to starting position, whilst the Multi-ranger deck allows for distance estimation to the above, left, right, front, and back of the drone. We now present the final 3 play experiences.

5 COLLECT THE BUTTERFLIES

The “collect the butterflies” game is inspired by the joy of aiming to “collect” butterflies by gently approaching them with subtle movements to direct them in certain directions. This play experience aims to primarily incorporate the sound, touch and proprioceptive senses via the ‘push’ and ‘pull’ concepts. The two drones used for this game were both equipped with Multi-ranger and Flow 2.1 decks, as the emphasis is placed on the drone’s movement in correlation to the user. After a 3-minute time limit, the drones will lower themselves to the ground to end the game. While the drones could potentially last longer than 3 minutes, the lower time was chosen to give a sense of urgency to collect all the drones.

This feedback cycle was developed to elicit a feeling the player was “guiding” the drone. As explored in the related work, this “guiding”, and “training” of drones results in players becoming more attached [6].

6 FLOAT THE BALLOONS

The “float the balloons” game is inspired by the game played with balloons, where players, especially children, would attempt to keep the balloon from hitting the ground. Therefore, the aim of this game is to prevent the drones from “falling” to the ground, with the player “raising” the drone up by placing their hand above the “controller” drone. When the player’s hand is above the drone, the drone will raise until it is 20cm away from the hand. The player must keep the drones from reaching the ground for the entire time period of 3 minutes, with the drones “falling” at a faster rate as the game progresses.

Like the first play experience, this experience primarily aims to incorporate the proprioceptive and touch senses through the ‘push’ and ‘pull’ concepts (Fig. 1). It uses 2 drones: one drone is equipped with a Multi-ranger and Flow 2.1 deck, the other drone with a Flow 2.1 deck and a Buzzer deck. This Buzzer deck allowed for an increased focus on the auditory sense of the player, providing more range to the sound produced by the drone, beyond the sound of the drone’s propellers.

The drones used are paired together so the other drone can provide the increased feedback to the player on the state of the game. This pairing is needed as the Flow 2.1 deck only allows for relative positioning to the ground, therefore if any obstacles are placed underneath the drone, the drone will shoot upwards to accommodate this new ‘ground’. Therefore, to allow the drone to sense a player’s hand above it, the Multi-ranger deck is required.

7 MATCH THE PIXELS

The “match the pixels” game is inspired by pattern matching games often played by young children. It aims to engage the player’s auditory, visual, and proprioceptive senses through the sounds and lights produced by the drone, and the careful movement the player must engage in to achieve the right match.

Similar to “float the balloons”, the drones are paired together, so one drone is able to provide the visual and auditory feedback, whilst the other drone is able to be an interactable controller. This is due to the limitations of the decks. In this game, two pairs of drones will display colours and sounds. These change as the player moves either of the ‘controller’ drones. The aim is to match the colours and sounds of each pair within the timeframe. The game ends after 4 minutes, the additional time was added due to how detailed the movements may need to be. This allows the player to experiment at the beginning of the play experience to understand what the movement of the drones do. Like “float the butterflies”, the feedback the drones can provide through their ‘physical presence’ seems key to encouraging the transition for bystanders to become players.

8 KNOWLEDGE CONTRIBUTIONS

8.1 Key Observations

Through the development and playing of the playful experiences, we derive three key findings.

Firstly, the pervasive drone-based play often resulted in collaborative play. Bystanders watching the game would often want to jump in to help the player, especially with the time-constrained nature of the play. We believe this is due to the pervasive nature of the play experiences we developed, in combination with the characteristics identified for drones in section 1.1.

Secondly, the suggestion of “design[ing] for simplicity” [2] we found to be particularly echoed within our own work. We found that the concept of the game should be able to be explained within a few sentences, otherwise the player may feel like they are spending more time understanding the play then engaging with it, especially as drone flight time is restricted by battery life. To echo on this “simple design”, with current drone technology, there is an ever-present trade-off to be made between drone-based sensors and adding other methods of feedback, such as light and sound. This is touched on briefly within section 4, as we are required to balance several aspects. As mentioned in our introduction, we aim to develop pervasive play through autonomous drones. Therefore, to provide greater autonomy to the drones, more sensors, and hence more decks, are needed. However, due to the design of Crazyflies, this results in less decks that can be used to provide feedback, such as buzzer decks or LED decks. As such we were forced to keep to this “simple design” for managing the number of sensors and other feedback on the drones.

From these observations, we distilled design strategies to be used by designers aiming to develop future drone-based pervasive play.

8.2 Design Strategies

Our first suggestion has to do with how players will interact with the drone. To link in with our earlier observations on designing for simplicity, the players must be able to interact with the drone in a natural manner, through gestures or the like. This encourages players to engage with the play, not focus on trying to remember each facet of movement.

Our second suggestion pertains to the strengths of drone-based play or play in the physical space. As the game happens in a physical environment, bystanders are able to more easily witness the game taking place. Seeing the player take part in the game can encourage the bystander to take part themselves, which they are also able to do easily due to the physical space occupied by the game. This has been echoed in our observations and ties in with our goal of generating pervasive play that can be played “with anybody”.

And finally, to further build on this idea of player collaboration, we suggest having an ease of disconnection between the player and a drone. For example, if there is time pressure for the player to handle another drone, it incentivizes them to move on, leaving an opportunity for other players to step in. This ease of disconnection further encourages collaborative play, as there are clear opportunities for bystanders to transition to players.

9 LIMITATIONS AND FUTURE WORK

With our current play experiences, we based them around the three aspects of pervasive play: “playing with anybody, anywhere, and anytime”. Currently, we have recognized that pervasive drone-based play lends itself to collaborative play and can be adapted to be played in any environment, touching on the first two aspects. However, we believe that to best explore the “anytime” aspect of pervasive games, it would include incorporating light into the play experience. This “light” could either include the LED light from the drone itself, or the daylight and lighting of the environment in which the game is taking place. How these two aspects interact could provide another facet to the drone-based pervasive play. Due to drone limitations described in section 4, we were unable to incorporate both LED light and ensure stable flight of the drones beyond the paired drones method seen in “match the pixels”. Additionally, exploring how drones can be interacted with outside of our push and pull concepts could lead to more avenues of generating playful experiences. This could include situations such as a balloon attached to the top of the drone that could be interacted with physically, or a cage around the drone the user could touch.

10 CONCLUSION

Throughout this work, we have explored how play can be designed using drones generating “Paida” play and noted various observations throughout the development process for use in future designs. We have outlined the limitations of the drone’s used, and where future work within this space could lead. . From these design strategies, we set a starting point for designing novel, pervasive, and playful interactions whilst regarding drones as pixels in the physical space.

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