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Towards a pleasurable human-drone interaction: the review of interaction techniques and drones' characteristics

(Prijetnejši interakciji med človekom in dronom naproti: pregled interakcijskih tehnik in značilnosti dronov)

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Izvleček:
V našem delu bomo shematsko predstavili pregled literature o značilnostih dronov in interakcijskih tehnikah, ki jih ponuja stroka, z namenom podčrtati dosedanje poznavanje možnosti za nemoteno in prijetno interakcijo med človekom in dronom. Prikazali bomo različne tehnike in metode, ki se jih človek poslužuje za interakcijo s to novo tehnologijo, našo pozornost pa bomo namenili tudi na faktorje, ki lahko vplivajo na naše sprejemanje le-te. Prav tako bomo pozorni na faktorje, ki spodbudijo v človeku lagodje: kateri je hipotetično najboljši način za drona, da se približa človeku, načini komunikacije namena in čustev človeku, odzivanje drona na človeka in obratno. Posvetili se bomo tudi z droni povezanim vprašanjem o varstvu zasebnih podatkov, etiki, kulturi in varnostu, kajti vzbujajo slednja ničkoliko skrbi pri uporabi dronov. Naša raziskava se je obenem osredotočila na šest najpogostejših temah, ki jih bomo izpostavili in podrobno analizirali na koncu našega dela.

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Abstract:
Our work presents a schematised review of the literature that revolves around drone characteristics and interaction techniques proposed by the field with the aim to point out the existing possibilities for achieving a smooth and comfortable human-drone interaction. We display various interaction techniques and different ways for humans to interact with this emerging technology, as well as how different factors can influence the acceptance of drones on human's behalf. We also cover different factors that can enhance the comfort in humans: the hypothetical best behaviour for a drone to approach a person, the manners to communicate its intents or emotions and the ways of feedback giving to the drone and vice versa. Topics we also concentrate on are privacy, ethics, culture and security in relation to the field, as the most common issues that emerge with drones usage. Our research has also drawn our attention on six distinctive prevalent themes that will be outlined and examined in more depth at the end of this work.

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List of Abbreviations

UAV	Unmanned Aerial Vehicle
HDI	Human-Drone Interaction
VR	Virtual Reality
HSI	Human-Swarm Interaction
DoF	Degrees of Freedom
BCI	Brain Computer Interface
EEG	Electroencephalogram
GUI	Graphical User Interface
IMU	Inertial Measurement Unit

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1 Introduction

We live in an era with digital technology interwoven with our lives and where innovators are constantly on a lookout for novel ideas. Due to the fast technological changes, people can also struggle to keep up with, accept and adapt ever-new devices as everyday tools. One of such technological advances happened with drones, also known as unmanned aerial vehicles (UAV). These are flying pilot-less robots that can be either autonomous or be controlled remotely. From the early ideas dating back to 1849 until recently drones were mainly used for military purposes. In the last two decades their use has expanded to a broad range of civilian applications such as for search and rescue missions, delivery services, agriculture purposes and photography among others. Advances in digital technology as well as materials have improved significantly drones' flying capabilities and nowadays drones can be equipped with a variety of high resolution cameras, GPS systems and other sensors providing new ways of use. Due to affordable prices their use is expected to keep increasing and consequently drones are to become part of our environments. The control of drones has always been challenging; however, since the use of drones is increasing, not only the understanding of how to properly control them becomes important, but also how to develop most appropriate ways of interaction between drones and humans. Therefore, it is important to understand how this novel technology is perceived by humans, how humans are willing to interact with it and which are the factors that could enhance acceptability of drones. The interaction between humans and drones has become of such great interest that the scientific community has started a research field that focuses on its understanding and designing: human-drone interaction (HDI).

The aim of our work is to analyse and categorise studies that have emerged in the past decades in the field of HDI. We focused on understanding and aggregating the knowledge uncovered as well as finding missing opportunities and future trends. We divided the thesis into several chapters based on the topics found in the literature. The next chapter introduces the topic and provides research questions that emerged in the field. Chapter 4 aggregates studies on different control modalities, known as interaction techniques, such as the use of body movements, gaze, speech, touch and brain-computer interfaces. Chapter 5 focuses on drones' characteristics that influence the interaction such as the trajectory of a drone, its altitude, shape, colour and various anthropomorphic features. The chapter covers also a topic on how to communicate drone intent using other signals as feedback such as light cues. Privacy, security, ethic and safety are also of high concern and seem to be the most common reasons that cause humans to object to drone use in public space and/or feel uncomfortable in the proximity of a drone: chapter 6 revolves around these topics. Chapter 7 covers various applications found in the literature including photography, search and rescue, sport, agriculture, delivery, healthcare and others. In the last chapter (8) we provide six emerging themes that summarise the research in the field. We further discuss the different methods, environments and drone autonomy employed in studies.

2 HDI Field

The field of human-drone interaction (HDI) investigates the effects and acceptance of the existing interaction techniques between humans and drones in the light of different drone applications as well as how they can be meaningfully expanded. Inspired by the interaction techniques proposed and adopted in the field of human-robot interaction, researchers investigated if such techniques can be appropriated when interacting with drones. But compared to land-based robots, drones can fly, and due to their flying capabilities a further investigation of interaction was required. So far, researchers were interested in exploring and answering research questions such as: *What are the preferred interaction techniques when interacting with drones?*, *Which interaction technique is more intuitive?* or others, more specific, such as: *Would users prefer touch interaction with a safe-to touch drone?*. Furthermore, researchers studied interaction preferences and evaluated novel interaction techniques.

The HDI community has also explored what factors influence interaction, and how to make it, in addition to intuitive, also comfortable to use and perceived as safe. Hence, the investigation included the understanding of how humans perceive the drone technology based on the combination of different flying parameters, posing research questions such as: *Which flying trajectory should a drone undertake when approaching a human?* or *At what height, speed and distance do humans prefer to interact with a drone?*. Physical characteristics of drones were also explored to increase users' perceived sense of safety and in consequence their acceptability. Since drones are expected to be fully autonomous in the future a new sphere of study has arisen that investigates drones from a social perspective as well as the possibility of drones to become our future companions. Interested in how this technology would better fit our expectations, researchers focused on drones' design space and which functions humans would like the drone to perform, posing questions such as: *What characteristics a drone companion should have?*, *Which functional values would people want from a drone?*, *How to make a drone trustworthy or friendly?* and even *Could this technology be perceived as a friend?*.

The research also tried to understand if humans can understand drone purpose and at which level people can recognise drones' "emotions". Various applications have also been explored from drones as companions in sport activities, drones as navigational aid, to flying displays that can project content onto arbitrary objects in the physical environment or can carry their own display or projection canvas while approaching users. All the envisaged scenarios predict that drones will become part of our everyday life and that they could support us in or carry out various tasks for us. Nevertheless, people usually show a great concern about drones, picturing the possibility of being hurt by them, feeling them as intrusive, and mentioning privacy concerns. Therefore, researchers have explored how to improve their acceptability to successfully integrate this technology while still addressing human needs. Even though HDI covers a wide specter of topics involving drones, a lot needs to be done to be able to fully integrate drones into the fabric of our environments and support a complete acceptance of drones by humans from every point of view.

3 Method

This chapter describes the method we used to explore the field of human-drone interaction (HDI).

3.1 Papers' selection

To understand the field, we conducted a literature search from June to August 2021 constructing a literature corpus of 148 papers found in several digital libraries, namely ACM Digital Library, IEEE Xplore and Google Scholar. We started by searching the term `human drone interaction`, which we then expanded with specific terms found during our initial exploration: `drone emotion encoding`, `social drones`, `companion drones`, `drone design`, `drone proxemics`, `drone applications`, `flying robots`, `human swarm interaction`, `drone approach`, and `UAV interaction`.

3.2 Inclusion Criteria

During our search we found an extensive number of papers on drones, several focusing on software and hardware specifications. We decided to use the below inclusion criteria to filter the set studies fitting within the context of our research. We considered the paper only if it:

(1) reports user studies in which participants directly interact with a drone;

(2) presents a drone prototype to be used around and with humans;

(3) presents a drone prototype that is intended to communicate to and/or interact with humans;

(4) outlines important aspects that should be considered in an interaction scenario with a drone;

(5) focuses on understanding what humans expect from drones;

(6) evaluates characteristics in a drone, which suit human preferences.

Some studies did not directly use a drone but were exploratory in nature. Some papers presented a prototype without a user study. However we decided to include them since they provide novel ways of both drone interaction and use.

We tried to organise our literature corpus into themes that emerged from analysing the literature: *drone design*, *interaction techniques*, *human preferences*, *social, companion and assistive technology*, *intent, approach and feedback*, and *safety, privacy security, ethics and culture*. In each of these themes we looked at the interaction from two points of view (POV): how can humans communicate their intent or desires to drone(s) and vice versa. These two form the basis for the next two chapters.

4 Human Interaction Techniques

In the past couple of decades drones' usage has moved from military usage only to various indoor and outdoor, commercial and personal activities such as video-recording, extreme sports, agriculture, and many others. This challenged researchers to investigate current and envision new use cases as well as explore interaction in existing and novel scenarios. Inspired by interaction techniques used in the field of human-robot interaction and trying to understand if methods used for land-based robots can be applied to flying robots, several interaction techniques have been proposed to make the interaction between people and drones as intuitive as possible.

In this section we are going to look at the ways humans can instruct or interact with drones. As humans use non-verbal (gestures, body movements, facial expressions), verbal communication and/or a combination of both to communicate when interacting with each other we decided to structure interaction techniques explored in the field of HDI by first dividing them in non-verbal, verbal and multi-modal interaction techniques.

4.1 Non-Verbal Interaction

In this section we present studies that explored a variety of non-verbal interaction. We have grouped them based on parts of the body (kinesics), that were used for interaction (*head movements, face poses, eye gaze, body movements, gestures, touch interaction*) and *brain-computer interface.* Note that some prototypes used more than one interaction technique and are mentioned more than once.

4.1.1 Head and body movements

One way of controlling the drone is with imitative movements, where the human performs a movement that is then repeated by the drone. Morishita et al. presented a prototype, where head movements and body postures were detected through a gyroscope and accelerometer positioned on user's shoulder and mapped to drone movements providing a drone-like flying experience [1]. More precisely, upright position was used to hover, forward body position to move the drone forward, left/right body movements to left/right drone navigation and diagonally left/right tilting for changing drone trajectory to the mentioned directions. The view of the camera mounted on a drone was displayed through a head-mounted display (HMD).

Head movements have also been used in FlyingHead [2] that allowed users to synchronise their head inclination, crouching and looking around with the drone in terms of horizontal, vertical position and yaw (vertical axis) rotation respectively. In order to track human movements, an optical motion capture system was used. A Wii remote controller was added to the system, to provide changes in altitude. In the study, the system has performed better compared to the regular joystick.

Google Glasses were also used to navigate a drone in [3]. More precisely by wearing Google Glass users were able to command the drone controlling the rotation of the drone with head movements. Additionally, users were able to issue other instructions via Glass' touchpad.

In another prototype a face detection system was used to determine if the person in drones' camera field of view is trying to interact with the drone [4]. A so called face score system was proposed on the basis of the orientation of the face in respect to the drone. To guide the drone to a certain direction and to cover a certain distance the angle between the center of gravity of the detected face and the hand direction was used.

In sport setting a drone can also move based on users' moves. For example, researchers have investigated drones as balls that could exhibit behaviours not currently possible with physical balls, such as floating, dodging objects, and defying gravity [5]. Such drone-as-ball or HoverBall can behave as a regular ball and react to different ways it is touched, pushed or kicked (see next section) as well as react to different body movements such as performing kick ups with a drone hovering above the leg without touching it. Another prototype used the drone as a sparring partner in boxing that avoided the punches of a human boxer as well as exhibited movements that the human had to avoid [6]. Yet another amateur drone based prototype played a table tennis and could move according to the ball passed by the opponent user [7].

4.1.2 Touch (haptics)

4.1.2.1 Direct touch

Touch in interaction is considered very personal and happens in a proximity to users. With the noise, fast rotating propeller blades, and size drones do not depict safe to touch objects. Despite this, some researchers explored touch-based human-drone interaction. For example in [8] researchers explored if users would use touch-based interaction when interacting with a drone based on whether a drone protecting cage was used or not. In a *wizard-of-oz* study participants were asked to use the interaction that felt most suitable for tasks being assigned. Gestures were mostly used; however, touch based interaction was the choice for 58% of participants when they were informed that the drone was safe to touch. Some participants mentioned that using touch modality felt "natural". Different types of interactions emerged from the study including the use of one hand only, or using both for grasping, pushing or pinching the drone.

Similar interaction has also been explored in Flyables [9]. Flyables is a cage protected drone levitating freely in space. Users can interact with it by touching it to shift it or can grab and drag it to change its position. The study revealed that users used one or four fingers when touching the drone. A similar idea was also investigating in previously mentioned HoverBall where a drone-as-ball could be interacted with as one would control a real ball [5].

4.1.2.2 Indirect touch

Not directly touching a drone but a remote tactile interaction method was proposed in MetroDrone [10]. The system consisted of an inertial measurement unit (IMU) and four virtual buttons, which provided the input for controlling and interacting. By tapping on virtual buttons the drone performed movements similar to dance, which looked like the drone was emotionally responding to the tapping beat. Based on the tapping pattern, the drone performed different trajectories, which could be used as an innovative input control and type of interaction. In addition, as the buttons were virtual, they could be placed anywhere.

Another not-direct drone-touching approach is for drone to project content on various surfaces, with which users can interact by tapping or touching interactive elements similar to touch displays. For example, the prototypes presented in [11–13] projected the content on the floor, which could then be interacted with by touching interactive elements with feet. More on these systems in section 5.6.

4.1.3 Gaze

Another interaction technique is a gaze-based control that provides some benefits over other techniques. For example, the use of gaze provides hands-free interaction, which could alleviate interaction also for disabled people. In the [14] researchers explored how the movement of pupils on the x-y axis can be employed to control speed, altitude, rotation and x-y movements of the drone. Several combinations between gaze and keyboard were tested, revealing that drone's rotation and speed were more reliable to control with the gaze, while x-y movements and altitude were better controlled by a keyboard. This result can be ascribed to the fact, that humans have to balance between the use of gaze for space orientation and drone controlling. In fact, participants always watched the obstacle they had to avoid, which caused the drone to move in the same direction and consequently crash in the obstacle.

In GazeDrone [15] gaze was not used to control the drone but to control the content on a public display. Drone was thus used as an intermediary in the interaction and it could adjust its position according to user's movements in order to track gaze. The study revealed that gaze tracking and interaction with the content on the display is feasible if users were interacting from a fixed position or when they were moving orthogonally or diagonally to a display.

4.1.4 Gestures

In this section we focus on mid-air interaction, where interaction is separated from the object users interact with (compared to on-object interaction, where interaction is executed on the object itself, which we covered in subsection 4.1.2). We will first present prototypes that supported predefined gestures following by studies uncovering proposed user gestures.

4.1.4.1 Predefined gestures

In their prototype Ng and Sharlin [16] proposed a falconry metaphor imitating gestures used to interact with birds in falconry. As falconers, users used their hand with a pad for a drone to land on or take off from. To instruct the drone to take off, users performed a pointing up gesture with their hand raised up. While for landing a pointing down gesture was used. To adjust drones' altitude users had to move their hand diagonally. Two more interactions were considered based on falconers commands: the circle hand movement to inform the drone that it should make a circle, and the find command (first providing information to the drone about the object to be found and then performing a pointing gesture to inform the drone where it should start the searching process). In addition, authors integrated the stop (by showing the palm) and come gestures (showing the back of the hand) by mapping them to the hovering state of the drone. The overall users' impression of using gestures for controlling a drone was positive; moreover, users found gestures to be more intuitive compared to a joystick controller.

A set of five metaphors to control the drone were investigated in [17]. These were (i) a first-person interaction metaphor, where users control the drone by imitating an airplane, (ii) a game controller metaphor, where users mimic the control movements of console joysticks with their hands, (iii) the throne metaphor, where users sit on an armchair and give drones commands by pointing, (iv) a proxy manipulation, where users imagine manipulating the UAV as if it were in their grasp by synchronously moving both hands in front of them, and (v) a variant of the latter called seated proxy manipulation. Besides controlling the drone's movements Higuchi et al. [18] defined gestures to inform the drone that a user would like to start the interaction (continuous double arm waving movement would bring the drone at a distance of 2 meters from the user) and how the interaction should finish (a waving bye bye gesture with both hands).

A set of predefined gestures was used together with deep learning in order to recognise gestures before they were even performed [19]. The system performed with a 53.86% accuracy. Researchers concluded that since some gestures are a combination of others, it is difficult to predict them. However, early recognition could improve communication and decrease response time of drones. Another two works [20, 21] also defined sets of gestures and body positions as intuitive ways to control a drone. For instance, the first study proposed to put the left arm in front of the user to command the drone to go backwards, while the second study proposed leaning back to move the drone backwards. All proposed sets are very different from each other, posing a question which one is easiest or most suitable for interaction. Despite the fact that the study presented in [17] showed that younger generations preferred gestures, it has been also shown that gesture-based interaction is neither more nor less intuitive compared to a joystick [22].

A multiple drones artistic exploration of drone equipped juggling balls was conducted in [23]. Users wore sensor equipped gloves and each drone was mapped to a single finger. To select a drone users had to tap the palm of the hand with a corresponding finger. The system allowed to control 5 drones at the same time, deciding from a set of 4 different trajectories, using hand gestures to create expressive drones trajectories. Researchers have also defined gestures for previously mentioned HoverBall such as "hover and glide" and "boomerang" to control certain drone-as-ball's movements [5].

4.1.4.2 User defined gestures

Several elicitation studies were conducted to find a set of user defined gestures. A study by Cauchard et al. [24] showed that users used both gestures and voice to complete predefined tasks that were to be done by the drone. Despite the fact that users mostly used gestures and for different tasks different gestures were employed, they combined them with speech commands where they sensed the "the lack of precision" of the former technique. This suggests that interaction should employ different modalities. Similarly, when firefighters were asked to envision how they would command a drone to enter a window from which a fire area would then be inspected, hand gestures were the first choice but several participants used them in combination with speech commands [25]. Inspired by [24], Obaid et al. [26] asked users to perform gestures to map the drone behaviour that was presented on a screen. Without explicitly telling users what the task was, it turned out to be difficult to interpret various behaviors of the drone, which not only leads to understanding the importance of gestures, but at the same time shows a potential possible scenario of users not understanding the purpose of the drone.

Some researchers proposed that different types of interactions could be more suitable for whether the user was standing or moving around. For example, researchers investigated which gestures would users use when running with a drone [27]. Results showed that users employ a variety of gestures from waving hands, multiple gestures, to full body gestures. However, similar gestures for the same task have been proposed in a variety of different contexts. For example when asking users to instruct the drone to take a picture, a common choice is to form a frame with thumb and pointing fingers of both hands [24, 27].

To explore interaction with a swarm of drones, Macchini et al. designed a virtual reality (VR) study in which they asked participants to first watch each of the eight actions the drones were performing (moving right, left, up, down, front, back and expansion, contraction) and consequently come up with a most appropriate body movement for each action [28]. The study revealed that hand gestures were the primary choice, but gestures for the same maneuver varied significantly among participants. This lead authors to create a personalised interface with two interaction techniques: remote control and hand gestures. The study revealed that participants learn faster how to use hand gestures for interaction, and despite showing no preference over the interface, participants found the hand gesture interaction to be more attractive and engaging.

4.1.5 Brain-Computer Interfaces

Brain-computer interfaces (BCI) allow direct mapping between humans' brain activity and controls of an external technology or device. The most common approach to capture brain signals is to use electroencephalography headsets (EEG), but other more invasive methods also exist. Although BCI are being developed primary for rehabilitation and healthcare purposes, their usage has spread to other areas such as HDI.

An experimental investigation was performed in [29]. Their approach relied on motor imagery, which is a mental process by which a person thinks of a given action. The study revealed that participants could quickly and accurately control the drone by brain activity. Other studies have also used the fact that motor imagery activates the areas of the brain responsible for performing the actual movement [30–32]. For example, researchers in [33] proposed the following interaction to control a drone: the thought of moving the right or left hand would move the drone right or left respectively, thinking of putting hands together or thinking on nothing would lift or land the drone.

Since the majority of BCIs for HDI rely on machine learning, this approach also requires long periods of training. In [34] researchers used a co-learning approach between the user and the drone in a motor imagery based BCI with affirmative feedback from users about the correctness of actions taking off, flying in straight line and landing. BCIs were also adapted to instruct a drone to change its altitude and perform rotations [35].

Besides controlling the drone, BCI was used for measuring the level of fatigue of drone pilots in order to quickly adapt drone's behaviour and prevent accidents. Interestingly, BCI was also used for drone racing competitions [36]. A comprehensive summary of BCI studies to control drones can be found in [37].

The motor imagery has been also used to interact with a swarm of drones [38]. Users were asked to perform a visual imagery according to the four proposed different drones behaviours: splitting, hovering, spreading and dispersing. The swarm of drones was presented on the screen by a group of points. The results showed a 46,7% accuracy across all users, which was also contributed to the fact that the drones were not realistic and were represented with dots on the screen.

4.2 Verbal interaction

In elicitation studies, speech was often used as a mean of interaction. For example, the results in [24, 39] showed that 38% of the interactions chosen by participants were speech commands for users from USA and 58% for participants from China. Peshkova et al. used online survey and interviews to gather users' suggestions for speech and gesture commands to navigate a drone; they proposed a set of speech and gesture commands to navigate a drone from users' preferences [40]. A further *wizard-of-oz* study showed that 25% of participant chose only voice commands, 25% chose only gesture commands, while 50% of them chose a combination of both.

Compared to other interaction techniques, the use of voice commands can be considered easier, but due to the loud noise produced by drone's propellers its use might not be favoured. Furthermore environmental noises and the drone distance can also impair its use.

4.3 Multimodal

The combination of different interaction techniques such as gestures, speech, body postures, head movements and others can enrich the interaction. It is still an open question, which interaction technique better suits a certain scenario, but it was showcased that people prefer using different techniques at the same time [24, 39–41]. Using only one type of interaction, could make the communication less intuitive or even in-effective. However, if the system requires the user to use multiple modalities at the same time, it can make the interaction stressful.

Elicitation studies mentioned earlier already showcased that gestures and voice commands are the primary choices when instructing a drone [24, 39]. The same happened with safe-to-touch drones where people used touch interaction in addition to voice and gesture commands [8]. Miyoshi et al. also proposed to navigate a drone using both hand gestures and voice commands [42]. Their system required users to wear coloured gloves, which were tracked by a camera equipped drone. Users could command the drone to take off or land using voice commands, while navigational commands, such as flying in a particular direction, were performed by hand movements. The use of gestures and speech commands were also investigated in [43].

Several interaction techniques were proposed in a framework called Aereostack [44]. It allowed users to interact with the drone by speech commands, body gestures, hand gestures and visual markers. It was up to users to decide on a combination of interaction techniques they deemed most intuitive. In addition, a graphical user interface (GUI) was developed for users to understand the behaviour of the drone and to choose various flying parameters.

Cacace et al. also developed a multimodal system to interact with a drone in a search and rescue missions using different interaction modalities (predefined gestures, voice, a tablet computer interface and a joystick) [41]. The authors proposed voice for movement, selection and exploration, and predefined gestures for navigation. Since search and rescue missions require effective and fast responses, the system based on the armband was developed to allow fast switching from one modality to another. To choose the joystick control users needed to open their hands, while closing their hands switched to the use of speech, gesture and the tablet computer.

When it comes to interaction between a swarm of drones and a group of people some authors have emphasised different aspects that should be considered when these two groups are co-located: how would people communicate with other people involved in the interaction, how drones would communicate with each other and how to establish a communication channel between drones and people [45]. Two factors were proposed in such interaction: environmental factors including other drones, which will help the drone to adjust its position to improve the performance of the mission, and situational awareness that informs humans why the drone behaved in a particular way. Even though voice and gesture based interaction was considered, authors decided to implement a GUI, to avoid ambiguity and because voice and gestures may be impractical in such situations.

As presented in this chapter, researches proposed and evaluated a variety of interaction techniques. Some studies aimed to find out how people would interact with a drone and which interaction technique better suits a certain interaction scenario, others proposed systems, which integrated a predefined set of commands to control a drone. All the aforementioned interaction techniques proposed in the field of HDI are schematised in Table 1.

Table 1: The list of studies and their focus on a particular interaction modality.

Interaction modality	**Single drone**	**Multiple drones**
Head and body movements	[2] (2013), [3, 4] (2014), [5] (2014), [1,6] (2016)	
Touch	[5] (2014), [8] (2017), [9] (2018), [10] (2021), indirect touch [11] (2018), [12] (2016), [13] (2015)	
Gaze	[14] (2014), [15] (2018)	
Predefined gestures	[16, 18] (2011), [17, 20] (2013), [5, 21] (2014), [22] (2015), [19] (2018)	[23] (2017)
User defined gestures	[41] (2015), [26] (2016), [23] (2017), [27] (2018), [25] (2020)	[28] (2021)
Brain-computer interface	[30, 31] (2010), [29, 33] (2013), [34] (2014), [32] (2015), [40] (2016), [35, 37] (2018)	[38] (2020)
Verbal	[43] (2010), [24] (2015), [40] (2016)	
Multimodal	[43] (2010), [24, 41] (2015), [44] (2016)	[45] (2020)

5 Drone Characteristics, Moving Behaviour, and Signals as Feedback

The increasing amount of services that emerged from the introduction of drones has inspired the human-drone interaction community to investigate ways a drone would communicate its intentions to co-located users. Different use cases were introduced in the literature, from drones being remotely controlled to entirely autonomous drones, bringing them into a public space and making them "social". In this chapter we cover drone characteristics and various ways listed in the literature that drones use to provide feedback, communicate intentions and provide instructions in order to bring understanding between users and drones. The reader should note that particular characteristics, moving behaviour and various other signals are not necessary in some drone applications such as agriculture. We are focusing on drones that will populate our public and private spaces and be co-located with humans.

5.1 General Approaching Characteristics and Proxemics

First, we describe the approach characteristics and factors of the drone that can affect people's comfort while a drone moves in their vicinity.

Proxemics

Proxemics refers to how people understand and use the space around them in social relationships and interactions. Edward T. Hall proposed the model of interpersonal distances, which includes 4 types of distances that people assume in social relationships: intimate (<45cm), personal (45cm - 120cm), social (120cm-300cm) and public (300cm>). Studies on proxemics focus on how drone's proximity affects people's comfort. This is usually studied in combination with other parameters that include the way a drone approaches users.

Trajectory

Since drones have 6 degrees of freedom (DoF) they can take different trajectories when approaching a person. For example, they can fly directly to users or approach them in an up-down movement.

Altitude

The altitude of a hovering or approaching drone is another parameter that can affect comfort. Many studies lack information at which altitude a drone was placed during the interaction and it is unclear if altitude has influenced the results. Nevertheless, some studies have investigated this parameter.

Speed

Different speeds such as slow approach, moderate and fast can also affect a sense of security and comfort.

Direction

People can also prefer a certain direction a drone is approaching them. If a drone for example approaches a person from behind, it may lead to a greater sense of discomfort. Studies of land-based robots showed that people tend to favor a right-hand approach rather than a direct one and this was also investigated in human-drone interaction.

Number of drones

In addition to the the above characteristics, the number of co-located drones can also affect the comfort of users.

A combination of the aforementioned parameters was used to understand what influences users' acceptance level of an approaching drone in several studies. In one of the earliest studies of drone proxemics [46] users were required to stop the approaching drone as soon as they felt no longer comfortable. Two altitude conditions were tested: 2.13m and 1.52m. In both the drone moved towards participants at a speed of 0.2 m/s. In addition, heart rate variability and psychological data were measured to better understand users' anxiety. Results indicate no significant difference between the drone approaching at a higher altitude in comparison to the lower one. The longest stop distance was 0.9 metres, which confirms that users allow the drone to enter their personal space. Users could not stop the drone at a distance shorter than 0.6 metres because of the study setup. Researchers could thus not verify whether users were likely to stop the drone at a shorter distance. Nevertheless, the studies presented in Section 4.1.2 about touch interfaces show that different safety cages encourage users to touch drones.

Another study investigated [47] drone approaching at altitudes of 1.2, 1.8 and 2.1 metres. In the first experiment researchers compared a comfortable distances of a social drone with a greeting voice versus a "non-social" drone at a constant altitude of 2.1m. The results show a decrease of 30% in distance when interacting with a "social" drone. The second experiment explored the proxemics sphere around users when the drone without a greeting voice passed by. Six different starting positions varying in heights and approaching directions were investigated. The study revealed that a drone approaching at an under eye-level height decreases the required acceptable and comfortable distance in an interaction scenario.

Social aspects, such as a greeting drone's voice, were also the basis of another two studies that explored accepted proximity [48,49]. Users were asked to walk towards the drone and to stop as soon as they felt uncomfortable. The experiment was designed with two different drones (big and small) and two altitudes (1.7 and 2.6 metres). In addition, the drone featured the voice of a participant's friend. As in previous study, users preferred an eye-level altitude rather than above-head one, but this result was not statistically significant. However, the experiment setup used a glass between the user and the drone to ensure safety, which might have influenced the results as participants knew they could approach the drone without any risk.

In [50] researchers explored 12 different conditions with three approach parameters: speed (0.25 m/s, 0.5 m/s and 1 m/s), trajectory (straight, up-to-down and down-to-up) and direction (front, front-right and rear).

Despite previous studies' conclusion that approaching from a front-right direction is most comfortable, participants preferred front direction over front-right and rear. Straight trajectory and moderate speed (0.5 m/s) were the preferred ones. The results also suggest that personal space was significantly preferred over social and intimate.

The authors in [51] used the Laban Effort System, a standard method for interpreting human motions commonly used in performing arts, in order to design the locomotion style (expressive motion paths) based on four motion parameters – speed, weight, time and the flow of motions were the parameters to define an approaching drone as being shy, aggressive, etc. The initial results show that "participants were all comfortable with the idea of robots communicating by expressive motion paths". A similar idea has been explored in twinkles [52] – drone-as-light companions for night walks that could exhibit 6 different types of movements from playful to more serious.

One study also investigated at which distance people want drones to acknowledge their presence [53]. Various conditions were explored: a drone approaching users and a human approaching a drone from two different directions (left and right) and with a maximum speed of 0.7 m/s. In the first scenario participants were asked to stop the drone as soon as they felt that that distance was enough for the drone to actively acknowledge their presence. In the second scenario users needed to approach the drone and stop when the distance was the desired one. The results suggest that the preferred acknowledgment distance is of about two metres.

A study of a delivery drone [54] showed that people prefer to stop the drone at a certain distance and then approach it, which made them feel more secure and comfortable. Another study found that female users let the drone closer [48]. A study that investigated differences in cultures when interacting with a drone showed that Chinese are willing to let the drone closer than the Americans [55]. Informing users that the drone was safe to touch also encouraged users to allow the drone to come into their intimate space [8].

Interestingly, the number of drones and how their approach affects users has not been investigated much. Macchini et al. aksed participants to interpret the actions of the swarm of drones and propose the best way to instruct the swarm to repeat it [28]. But besides interpreting swarm actions, they did not investigate how swarm actions can affect users and their attitude towards the swarm. Several studies focused on algorithms to avoid collisions between drones and on communication among them during flying to complete a common task [56,57], yet, how users see and interpret these movements has not been investigated.

5.2 Physical characteristics

Size Advancements in drone technologies have made it possible to produce a wide range of models in different sizes. Some studies have taken drones' size into account to understand if it alters the way users perceive the drone.

Noise

The noise emitted by drone propellers can highly affect the interaction. Participants in several studies argued that noise was one of the factors that made them feeling uncomfortable when the drone was approaching them. Therefore, it can limit the acceptance of drones in in both public and private spaces.

Shape

Drone shape is another characteristic that has an impact on how drones are perceived by humans. Several studies showed that people react differently to distinct drone shapes.

Colour

Besides shape and size, drones ant their parts can be manufactured in different colours and can play a crucial role in making interaction more or less comfortable.

Preliminary works on drone prototypes suggested, that a drone with a rounded *shape* [48,58,59] increases acceptance contrarily to a cubic-shaped drone. *Size* was also observed as an important characteristic. The results of an online questionnaire of the the characteristics of a social drone as a companion suggested that small and medium drones are more acceptable than big ones [58]. This was also used as a parameter in the aforementioned study of drone proxemics [49] resulting in the decreased social distance for smaller drone. Even though such results might seem obvious, there is still a need to evaluate both characteristics at the same time to determine the best possible human perceivable system.

Another studied feature is *colour*. Different colours evoke different feelings and emotions in humans. For example, a dark drone can be perceived as likely to attack by some [59], whereas others perceive darker drones as more mature and intelligent [60]. More colourful drones are perceived as friendly, trustworthy and likeable [60]. People perceive blue coloured objects as cute and for this reason a blue drone was chosen to be evaluated in a proxemics study [48]. Interestingly, the significance of drone's colours has also been proposed as an attribute that can be associated to a different community [61].

The last characteristics is *noise*. It has been mentioned in several studies as one of the factors that can increase anxiety [62–64]. However, propellers' size, design and shrouds can slightly alleviate this.

5.3 Drone's Task Dictating the Shape, Movements, and Other Feedback

Researchers also explored how would drones' design based on their role in our lives, functionality, and personality make them more acceptable. Drones as companions can spend significant chunks of time with users that can also develop personal attachment as explored in [65]. Majority of participants involved in the study found a drone more appealing if it offered both functional and hedonic values. Among four options (bully, servant, friend and pet) participants were keen to see drones as potential friends or pets. In addition, the level of control they would like to have depended on the situation, with fully automatic considered as not suitable. Also, predictability of drones behavior would make a drone seem a funny companion.

Researchers also investigated user preferences for drones in a home environment [58]. Similarly as in the previous study, participants proposed that drones should focus on helping out with home tasks (58.3% agreed that drones could be used at home) in addition to using them for playing as if they were a toy. However, contrary to the previous study participants did not consider drone as a friend with which to personally interact. But they proposed some additional roles such as drones as bodyguards. Also in line with the previous study, participant mentioned that drones should not be fully autonomous.

Drones as safety companions were proposed in [66]. Such drones can accompany people home at night in order to decrease anxiety and worries about walking alone in the dark. The drone communicated its actions (e.g. changing the altitude because of the wind) to users over a smart watch in two different ways: with emotionally written sentences and drone emoticons or with neutrally written sentences without emoticons. A similar idea to improve urban safety using drones involved the so called above mentioned twinkles [52]. Their authors took the role of the drone into account and designed them in a form of flying lights that strengthen a person's sense of security and safety. Different drone characteristics such as speed, altitude, glim and amount of light were the key in conveying drones' behaviour. Combinations of them led to the finding of six different twinkles - from a puppy, the nicest twinkle to the guardian angel, which increases perception of security.

Different drone movements were also used to help people navigate [62]. For example, different distance and altitude together with different motions of the drone revealed to users where to go. Despite the positive attitude from participants, concerns about the noise were mentioned as in other studies [24,62–64]. Nevertheless, researchers have shown that drone's noise can serve as a navigational guidance for visually impaired people [67]. Users perceived the prototype as easy to follow and use. As such navigational aid could be hard to use in noisy environments, in addition to noise emitted by the drone, Soto at al. proposed a tactile feedback through a handle connected to the drone by a leash [68]. Nevertheless, participants preferred sound only feedback. A similar approach with a leash between the drone and user's fingers was also used in a prototype called GuideCopter to help blind people with object localisation in unknown environments [69]. The study showed that such fine-grain haptic feedback achieves greater accuracy compared to a current audio-based hand guiding systems. Companion drones "on a leash" were also envisioned to be used to expand users' view with a drone attached to the wrist by a wire while charging batteries at the same time [70].

A lot of work has been done on drones as jogging companions [27, 71–73]. Some researchers explored whether such technology will be adopted by runners, others investigated which interaction modality could be suitable for a dynamic interaction during running. Participants also proposed new applications, such as carrying runner's belongings and video-recording. Such approach has been shown successful also in guiding visually impaired participants to run following the drone's sound [74].

Depending on the context in which a drone is used, people in the surrounding environment can interpret/accept technology differently. For example, assisting drones can improve the quality of life of impaired users, but at the same time cause concerns for co-located people who do not directly benefit from this technology [75]. Only when their safety would be ensured participants in the study agreed with the use of drones as assistive aids. On the other hand, blind people were preoccupied of the fact that they already attract attention, which would be exacerbated with drone use.

5.4 Emotion Encoding in Drones

A large body of work on interaction with drones mentions that when people are asked to interact with a drone they consider and treat them as animal-beings or even as friends [8,24,39,44,51,60,76]. This fact indicates, that integrating anthropomorphic and zoomorphic features in drone has its advantages and can highly increase human acceptance. Research on human-robot interaction has proved that adding emotional components to robots substantially increases human acceptance of them. This has led to studies on how to express different emotions in drones, despite the fact that in one study only 50% of participants agreed that drones should provide emotional features [58]. Several ways of expressing emotion in drones were found in literature: drone's motion, voice, colour and facial features. These are presented in the next subsections.

5.4.1 Emotions Through Motion

Motion has already been mentioned to express different drone attitudes such as in the above mentioned prototype based on the Leban Effort System [51] and walking companions lights twinkles [52]. In the former system a drone that was moving fast and performed quick movements, was perceived as a happy drone with a lot of energy. While a drone moving slowly was perceived as less excited and not happy. In another prototype called Daedalus, the emotions were mapped to drone movements of head roll and pitch head movements [64]. In addition, the drone used white or red eyes and propellers on and off. Users needed to choose the most appropriate emotional state from a set of given emotional states based on the combination of parameters mentioned. White eyes were mainly attributed to positive emotions, red eyes to negative ones, while propellers being on increased fear.

Szafir et al. also proposed to express drone's intent by modifying motion parameters such as trajectory, orientation and velocitiy [77]. The results show that users are able to recognise intent of the drone from the proposed flight movement in both exocentric end egocentric points of view. A further study confirmed that users prefer manipulated motions, that such motions are considered to be more intuitive than the "normal" ones, and that users feel safer interacting with the drone exhibiting such motions.

With a similar aim, Cauchard et al. [78] used personality stereotype models to describe seven personalities mapped to drone traits (speed, altitude, reaction time, and special movements), which led them to identify an emotional model space that includes four personalities for drones: exhausted drone (Dopey/Sleepy/Sad), anti-social drone (Grumpy/Shy), adventurer hero drone (Happy/Brave) and the sneaky spy drone (Scared). When asked to interpret drone's emotional state (afraid, brave, dopey, grumpy, happy, sad, shy and sleepy), participants easily recognised the adventurer hero, but anti-social and exhausted drones were more difficult to recognise. The study shows that humans can interpret drones' movement and flying path and attribute emotions to it.

Expressing emotions with movements was also proposed in [79]. Authors mapped variations in speed, rotations, altitude and distance as well as some special movements such as flips, hovering, closer movements and others to five different human emotion states: anger, happiness, sadness, surprise and fear. For instance, a happy emotion was announced by the drone flying faster, with rotation movements, flips and twists on persons' eye level and entering human personal space. Hieida et al. also used a combination of movement parameters, such as acceleration, velocity and trajectory to display drone's emotion [80].

5.4.2 Voice and audio feedback

We have already mentioned a better acceptance of drones using voice to greet users while approaching them [47–49]. Voice based instructions from the drone for users to follow were proposed also for a delivery service [63]. In the same work, audio feedback was proposed to inform users of certain actions that would take place next such as taking off. Audio feedback was provided also for acknowledging users' input [15]. To help blind people find their way around a space, DroneNavigator [67] used speech commands to set the navigational path. The drone then used sound emitted by its propellers airflow to inform users which direction to choose and follow. Other studies also confirmed that blind people can accurately follow the drone by following the noise emitted by the drone and that can easily locate its position [67, 74].

5.4.3 Colour

The use of colour can also make users to attribute certain characteristics to drones such as dark colour perceived as dangerous [59] or intelligent [60], lively colours as friendly, trustworthy and likeable [48, 60]. It was also mentioned that there are differences between cultures [61].

5.4.4 Facial Features

A study on a use of drones as social companions showed that 50% of participants wanted facial features to be embodied in the drone [58]. Moreover a 83,3% of users proposed that drones should have body extensions like arms, that can be used to carry things. In the final experiment where participants interacted with a drone in a VR environment a high percentage of them preferred to interact with an anthropomorphised drone. The desire to make a drone more similar to humans by adding *facial features*, like a mouth and eyes, was also expressed in [48].

A study that evaluated physical characteristics of a drone from a set of chosen drone models on the market revealed that drones with a mouth were perceived as more trustworthy and child-like, while a drone without mouth was considered as more intelligent [60]. In a study about understanding facial expressions from drones featuring eyes, eyebrows and mouth, the mouth was the most frequently named facial feature [81]. This indicates its potential to be used on social drones for users to be able to interpret drone's intention.

The use of red (negative emotions) and white eyes (positive emotions) has been used in the above mentioned Daedalus [64]. Expressive black and white eyes were also used for expressing emotions through drones responding to the emotions of humans (happiness, sadness, anger and neutral state) [82]. Findings showed that coloured eyes on drones are perceived as more masculine, while dark ones more feminine, providing an insight that people can also attribute gender to drones [60]. Adding eyes to drones proved that people were willing to interact more with them and perceived them as more intelligent, likeable and friendly. Others showed that drones with red eyes elicit in users a high sense of fear and attribute anger to the emotional state of the drone [64].

By using eyes, eyebrows and mouths, a cartoon-like set of six facial expressions (joy, sadness, fear, anger, surprise and disgust) with three intensities for each, was proposed to be integrated on a drone [81]. The study showed that people easily recognise emotions on drones together with their intensity. Interestingly, the drone's facial expressions evoked a reciprocal response in participants. Static and dynamic facial expressions were also discussed and analysed: results showed that people's recognition rate for static ranged from 62 to 95%, while that for dynamic stimuli ranged from 43 to 99%. Moreover, people can show affection towards the drone (e.g. worry about drone's state) and can also make narrations involving the drone, co-located people and the environment.

5.5 Light Cues

Light cues are used in a variety of situations including airplanes to convey their presence in the sky, traffic lights that use different colour to indicate how to behave, and emergency vehicles such as ambulance, police cars that inform us that there in an emergency.

Inspired by such visual cues researchers in [83] embedded four types of light behaviours on a LED shaped in a circle attached to a bottom of a drone to communicate its intent of direction. Four variants of visual cues were proposed: (i) blinker, based on cars indicators to communicate if the drone is turning right or left, (ii) beacon, to show direction by pointing the way with light, (iii) thruster, based on the idea that light somehow pushes the drone, and (iv) gaze, which is a combination of two lights representing human-like eyes on the mounted led ring. Participants were able to understand the meaning of lights and the blinker has been found the most intuitive.

Inspired by the proposed light system Monajjemi et al. [84] used coloured lights as feedback system mounted in front of a drone to communicate its intent by changing different colours and patterns, which were based on different metaphors such as a radar scanner behaviour for searching and a gaze light pattern during the interaction.

5.6 Flying Displays

Besides the possibility to provide feedback on a remote tablet computers and smart phones in user's hands [41], drones have a capability to move quickly anywhere, adapt their position to user orientation and field of view, and project information on a variety of surfaces creating the so called flying displays. Such displays can be used in emergency situations, for providing navigation, and communicating various information to people.

The FlyingDisplay [85] is a system that consists of two drones where one is equipped with a projector, while the other carried the canvas. Another prototype carried both the projector and canvas on a single drone [86]. The system also allowed users to send messages to the drone, that were then projected on the canvas. Other researchers proposed to project the desired content such as navigation, games and other instructions directly on the floor or walls [11–13].

Since projecting content is usable only in low light conditions, Schneegass et al. [87] built a prototype that carries a flat screen to display information. A similar system with a screen was proposed in [63]. Another prototype iSphere used a spherical display on a sphere cage around the drone [88]. Another approach is to first anchor the drone to a surface, for example a wall, turn off the propellers and then project the information [89] in order to have a less noisy and safer projection of information and thus improve user experience.

5.7 Haptic feedback (in VR)

Besides the two mentioned prototypes providing tactile feedback for visually impaired people (a tethered drone to a user's hand used for navigation [68] and object localisation in unknown environments [69]) such feedback has been proposed for VR environments. Drones can dynamically position themselves anywhere in short time providing physical objects in the same place where they are positioned in VR. For example, Kniermin et al. [90] used drones for haptic feedback with the use of mini drones that simulated bumblebees, arrows, and other objects hitting the user in VR. Abdullah et al. presented a system providing force feedback called HapticDrone [91], which could be either positioned on a hand pushing downwards giving a sense of gravity of an object on hand, or placed under the hand pushing upwards giving a resistance sensation of an object under the hand.

Another prototype consisting of a drone with a paper sheet attached on the side provided several possibilities [92]. It could act as virtual unlimited wall by moving where the user expected it to be or it could provide a reaction force by the airflow produced by its propellers. In a study participants were asked to draw a line in VR on the wall and stab virtual objects using a physical sword-like item. Results show that participants liked such haptic feedback.

HoverHaptic [93] allowed users to grab the object in VR by physically grabbing the drone and move it to another position. Texture mapping was also used to add different textures to the drone. In addition, drone was equipped with a grasping mechanism capable of picking up various light-weight objects. A study showed that participants were not feeling comfortable touching the drone, resulting in retracting their hands. One reason might be uncertainty of what they were really touching. The most exciting task was the part where users could really take an object and move it. They perceived that their touch actually mattered and could somehow affect the virtual world.

The above mentioned systems used only one drone at a time. In a prototype WiredSwarm, a swarm of drones attached to gloves with wires that were worn by the user could produce vector forces in many directions and manipulate user's fingers [94].

A summary of particular drones' moving and physical characteristics that affect interaction is presented in Table 2. Table 3 provides a list of studies that focus on different drones' moving behaviours, and other signals to provide feedback.

Table 2: The list of studies and their focus on a particular moving and physical characteristics when drone(s) is(are) approaching users, which are affecting interaction and can communicate the intent.

Drone Characteristics	**Reference (year)**
Proximity to drone	[46] (2013), [8, 47, 48, 55] (2017), [49, 53, 54] (2018), [50] (2019)
Trajectory	[50] (2019), [51] (2013), [52] (2018)
Altitude	[46] (2013), [47, 48] (2017), [49, 52] (2018)
Speed	[52, 53] (2018), [50] (2019)
Direction	[53] (2018), [50] (2019)
Flying movements	[51] (2013), [77] (2014), [78, 80] (2016), [52, 79] (2018), [82] (2019)
Number of drones	[28] (2021)
Size	[47, 48, 58] (2017), [49] (2018)
Shape	[48, 52, 58, 59] (2017)
Colour	[48, 52, 59] (2017) [60] (2019)
Facial Features	[64] (2014) [82] (2019), [81] (2021)
Voice	[47, 48] (2017), [49, 63] (2018)
Noise	[64] (2014), [24] (2015), [62] (2017), [63] (2018)

Table 3: The list of studies that focus on different drones' moving behaviours, and other signals to provide feedback.

Drone Feedback	**Reference (year)**	**Multiple drones**
Audio Feedback	[47, 48] (2017), [15, 49] (2018)	
Light Cues	[83] (2015), [84] (2016), [52] (2018)	
Projector and Screen	[87] (2014), [86] (2016), [88] (2017), [63] (2018)	[85] (2014)
Projection on Surface	[13] (2015), [12] (2016), [11, 95] (2018)	
Haptic Feedback	[92] (2016), [68, 91] (2017), [93] (2019) [69] (2021)	[90] (2017), [94] (2019)

6 Human Concerns

This chapter focuses on concerns humans have about drones and various ethical and cultural issues that evolved around drones and have been found during our literature research. First, we describe studies that focus on privacy and security. We then discuss safety and ethical issues that aroused in the field and we conclude by presenting studies that pointed out how cultural differences influence the interaction and the perception of drone technology.

6.1 Privacy and Security

There is a distinction between controllers' and bystanders' perception of privacy [96]. While bystanders tend to feel discomfort and show their preoccupations towards their privacy being violated by drones taking videos, photographs or recording audio, or even just providing insight into their homes, controllers' concerns seem to be focused primarily on safety. Considering that issue of privacy violation is strictly related to the delimitation of public and private area, several volunteer drone controllers have been asked to give their opinion about what is private and what is public to them. A further confrontation of their answers and lawyer consulting has shown that their knowledge on this topic is not sufficient. However, as it emerged in an earlier study about people's privacy perceptions of drones [97], context plays a decisive role in such discussions. For example, after having considered that a mall could possibly be a public space, an interviewee has underlined that a conversation taking place between her and her friends in such location is still private, therefore, recording such conversation has to be considered as a violation of privacy.

A thorough analysis and confrontation of the answers given in the above mentioned interview, helps to define two main issues on privacy violation: the first one is the concern of the drone being capable of gather an enormous amount of data, while the second one is the impossibility to know who the controller of the drone is. These two issues may help to understand why the use of cell phones and similar devices in public are not considered to be so intrusive – as stated by one the interviewees, it is easier to ask the photo taker to erase a photo from their phone than to find who controls the drone in similar circumstances. In addition, being small sized, drones are capable to reach certain spots without being noticed. This automatically raises the problem of the consent of being recorded. Many participants in the survey expressed the need to define more strict and specific rules for controllers to gain the consent for the recording taken. Since we live in a society that highly values privacy, people have the need to be informed and notified when being filmed by a drone. A drone driving license and training to overcome the issues mentioned have been suggested. As CCTV cameras for security purposes are present in our environments for decades, it is interesting to notice, that people are more comfortable with such cameras compared to drones even if their purpose is the same. This also applies to drones being used as police reinforcement: no matter if drones are faster, more precise and discrete, people seem to be very skeptical nonetheless.

Another survey has also shown how people differently react to various scenarios in which they have to imagine themselves facing a drone [98]. The answers usually differ on the basis of different variables given from case to case: people manifested interest about who was controlling the drone and collecting data, when the data was collected, and how the collection happened to come. Additionally, people were led to change their feelings towards privacy violations thanks to different examples of privacy-preserving technologies presented to them. Authors distinguished six different examples or techniques that could be possibly employed to preserve privacy in the process of data collection with drones. One is physically move the drone to a different area to prevent data gathering or point the camera of the drone in another direction. Face blurring during filming, can be also implemented. Another possibility is to indicate when and which data the drone is collecting by for example showing this on a display. Other option is to create an application, which makes it possible for individuals to possess the means to query a drone that is located in their proximity. The last option proposed was to add an indicator to drones such as a sign or a certification (both digital or physical) to ensure people about the drone's trustworthiness.

While the majority of studies focus on privacy concerns caused by drones, some researchers propose the use of drones exactly to prevent data stealing and to guarantee peoples' privacy [99].

Others aspects about the integration of drones into communities such as safety were mentioned: it is very clear that the line between privacy and safety can be very subtle. This is the case of [61] when participants proposed drones to help people in rural communities to increase safety. At the same time others have consequently shown concerns about their privacy being violated in such case.

6.2 Perceived Safety

Participants who took part in the evaluation process of studies described in previous chapters have expressed safety concerns. For instance, people are concerned about their safety if the drone is not far enough when they interact with it [59]. However, if people are aware that drones' propellers are protected by a cage, they perceived the interaction to be safer [24,47]. Yet, others have argued that drones' propellers protected by a cage were perceived as less trustworthy or friendly, and that people were less likely to interact with such drones [60].

The drone's flying behaviour and its aspects elicit different feelings in humans. A study has shown that people feel safer if drone's movements can project certain characteristics, compared to a direct flight path [77]. The results also show that people prefer interacting with an algorithm-driven drone rather than a human-driven one, during a drone tour guiding scenario [100]. Thus, the level of perceived safety may enhance the level of acceptance of drones. Studies used different approaches to ensure safety when participants were asked to interact with the drone. For example, Han et al. placed a safety glass between participants and the drone [49], others proposed to attach the drone to a tripod [27] or ceiling [46]. While such setup can ensure safety during studies, the results may not reflect real life scenarios. For this reason, the most common approach was to control the drone remotely by a hidden pilot without revealing to participants that the drone was not autonomous (these are called wizard-of-oz studies).

Using scenarios close to reality also allows to explicitly understand the concerns human have and why they feel not safe when interacting with drones. In addition to distance and propellers, studies also mentioned the noise emitted by propellers and visual aspect of drones. But the most common concerns are that people do not feel safe, because of possible malfunctions causing the drone to fall, and because their movements are unpredictable. Their intent, purpose and factors such as who is navigating the drone are in many cases unknown, which increases the sense of risk.

6.3 Ethics

Ethics is a branch of philosophy that "involves systematising, defending, and recommending concepts of right and wrong behavior". We could say that drones are an extension of human behaviour and are consequently dependent on people's will. So are other people affected by drone behaviour. Therefore, the employment of drones leads to a great number of ethical issues.

To analyse possible ethical issues researchers have divided drones on the basis of their role, namely: drones for commercial/civilian, leisure and military purposes [101]. The most obvious ethical issue in the military domain is killing, which is itself considered to be a non ethical act. No matter the level of their autonomy, drones are still not fully autonomous, meaning that users still have a certain degree of decision power. On of the major concerns is the future possibility of drones to become fully autonomous killer machines [102]. One of the ethical questions is whether humans will experience remorse in the incidence of automatic killing.

Other domains' ethical issues mostly evolve around privacy [101,102]. As mentioned before, drones used for leisure activities, such as photography, can easily violate privacy in public space. Furthermore, the use of drones can be very disturbing to users who want to calmly enjoy a public space. And often a person benefiting from drone's activity perceives it very differently compared to co-located users who are just bystanders. Additional issue include a substitution of human workers by drones [102]. Is it thus ethical to use drones or not? Are drones a threat to people or can they provide extensive benefits to our society? In general, we can say that it depends on their employment and the only way to limit or prevent both ethical as well as physical damages, is setting and respecting specific rules and protocols for the use of drones [102].

6.4 Culture

How to design culturally independent and at the same time intuitive interaction has been revealed to be one of the challenging parts in the research of HDI. Gestures for example vary from culture to culture: ones that are considered to be positive in one culture can have a different meaning in another culture. Different interpretations can lead to misunderstandings during interaction. Moreover, people behave differently in different cultures as well as have different attitudes towards novel technologies.

Some researchers decided to limit their studies to a particular cultural group. For example, authors in [58] explicitly say they decided to limit the study only to Swedes to prevent cultural impact. Others were looking at how cultural differences impact interactions such as between Chinese [55] and Americans [24]. The studies have shown that among gestures used by participants, some were culturally specific, and that the Chinese used more voice commands compared to US participants and allowed the drone to come in closer proximity. Nevertheless, in both studies participants anthropomorphised the drone, interacted with it as if it were a person/pet, expressed emotions and showed respect towards it.

Participants in a co-design workshop conducted in Africa [61] emphasised that drones should reflect community values, moral principles and traditions. This is, depending on the community the drone should behave differently and be in some way an extension of that community. However, they did not discuss the case when people of different cultures are co-located. Some participants believed that the social status of a person affects the level of the responsibility required for using drones.

Two different approaches can be taken: the integration of drones in our landscape can either take sociocultural differences into consideration or try to make the interaction between humans and drones culturally independent while at the same time compatible with general cultural values.

7 Applications

In this chapter we will look into some use cases of drones proposed and explored in the literature surveyed.

7.1 Photography

One of the most common uses of drones is photography and exploration of areas that can not be directly reached by the user. Such technology is very appealing for photography journalism, amateur photographers to take photographs from the point of view not easily reached by humans as well as for selfies [103], and filmmakers.

7.2 Search and Rescue

Drones provide a fast and cheap response during search and rescue missions, which allow responders to, for example, search for a missing person in large areas in short times. A more complex scenario of multiple people and multiple drones used in emergency situations was considered in [45], where the authors explored the situation where multiple users needed to be engaged collaboratively with multiple drones.

7.3 Sport

In the context of sport activities, several papers have illustrated a variety of use cases. The use of drones as a jogging companion was proposed in different studies [27, 71, 72]. Some of them had the goal to evaluate the users experience while using such supporting technology (companion, pace keeper, error and performance detector, observer, coach), while others investigated gesture interaction in the context of a dynamic scenario during running.

HoverBall [5] is a drone-base prototype designed for expanding possible interaction with balls. Presented in a form of a ball, the drone uses touch, body movements and hand gestures to control the drone movement. Researchers proposed that such a drone could auto-tune to different players' skills allowing children as well as elderly to participate in games equally. In a boxing context drone was used as a sparring partner during training [6]. For example, the boxer had to perceive drone's movements as well as drone needed to avoid boxer's punches. The authors have also suggested the drone could analyse sensory input from boxers and provide instructions and direct feedback to the user. However, how this would be done was not discussed.

Users adopted drones for back-country activities such as climbing, hiking and cycling or serve as a guidance during a walk through a forest [104]. And in a recent YouTube video drones were used as a pin-pong player, involving it in a one-to-one match and a two-to-one play [7].

7.4 Entertainment

Exergames are types of video-games that involve human exercise during the game. Researchers envisioned drones for exergaming, due to their ability of being located everywhere in the environment. StreetGamez was proposed as a type of exergame, which uses a drone and a projector to show and move the game elements on any surface [13]. The authors proposed both fixed game surfaces such as tic-tac-toe and moving game elements such as catching a moving object. A similar work called LightAir also projects different types of games on the surface [12]. Users could play virtual football, the piano and watch a map to ask the drone to calculate a path.

7.5 Agriculture

In recent years, drones have been increasingly used for agriculture purposes. They allow farmers to constantly monitor their ground conditions by air, can be used for crop dusting and spraying, which can highly reduce the exposure of pesticides to farmers [105], and were also proposed as planting systems, to help with irrigation and as health assistant for crops [106, 107].

7.6 Healthcare

Drones were also adopted as medical suppliers. Since some areas can not be easily reached by humans, because road networks are non existent or simply because drones are faster that other modes of transportation, drones can help to transport medicines, medical equipment (e.g. defibrillators), and other supplies (blood, organs) providing communities with essential health care [108]. In addition, at the time of the Covid pandemic drones have been used to disinfect public places and check body temperatures, besides public space monitoring and guidance during lock-downs [109, 110]. Moreover, visually impaired people and people with disabilities can improve their lives with the help of drones [67–69, 74].

7.7 Delivery of Goods

Besides the delivery of medical supplies, another promising application is the delivery of goods with drones to people. Examples include drones developed by companies such Amazon with its Amazon Prime Air [111], UPS with Flight Forward and DHL. Some proposed drones for delivery in smaller locations such as on a university campus [63]. A survey revealed positive feedback from people who used the system, but some concerns were voiced: a smoother flying path needed, the lack for instructions from the drone and the noise. Tan et al. investigated drones for a delivery service to find out how and what people desire from such service [112]. Even though such technology can be advantageous people still have many concerns about delivery drones, such as privacy, security and at the first place safety.

7.8 Other

In addition to the applications described above, a recent article tried to extract from social media what other applications people expect and desire from drones [113]. By examining various Instagram, Youtube and TikTok posts, the authors categorised six potential groups: drones for enhancing social connection, drones to challenge games, the use of drones for delegating everyday tasks, making pranks with drones, drones as an aerial artistic medium and making drones to be more human-like.

Even if, as we have already pointed out, the major concerns about drone happen to revolve around privacy and security, authors from [99] suggested to use drones as interactive privacy interfaces, that could guarantee data flow and privacy in a smart home environment.

8 Discussion

This thesis aims to provide a comprehensive review of the HDI academic literature. During the exploration of the current state-of-the art of the field several research questions have been found in papers, which have helped us to identify six different prevalent themes presented in this chapter. Although we divided the thesis so far into human-drone interaction techniques, human concerns and applications, these six themes overlap with them. Further, we focus on study methods, the environment type used in studies and provide a discussion about drone's autonomy. We conclude our qualitative analysis by describing in which direction research is evolving as well as which are the missing opportunities and future trends.

8.1 Prevalent themes in interaction

Drone Design. Studies on drone design focus on identifying physical characteristics that would satisfy people's preferences and should make the interaction with drones more suitable to them. This group of papers try to answer questions regarding which physical features of drones affect interaction/acceptance (e.g. colour, shape, size, etc.) considering also different context in which drones will be used. Some examples of question from articles are: *What size should the drone companion be?* [58] or *What are the characteristics that will help us design drones in the future to fit users' expectations?* [60]. Other human-like properties, such as adding month, eyes, eyebrows or even dynamic face expressions were proposed to be integrated into drones [64,81,82]. It was showcased that such properties influence people's perception of drone technology and that people ascribe various personalities based on different characteristics of a drone. Therefore, the integration of physical features affects how this technology is perceived and understood by people.

Although some articles have investigated the matter in detail, we have noticed that only a small percentage of the articles try to identify which physical characteristics lead to a smooth interaction and higher acceptance. Therefore, understanding exactly which drone physical features trigger particular felling or responses from people could help to better integrate this technology.

Interaction Techniques. As extensively described in the thesis, the idea to control a drone has moved from the use of well known joysticks to the employment of other control modalities focusing on how to make the interaction between humans and drones as intuitive as possible. Thus, a great number of studies explored the use of different interaction techniques that may enhance the interaction. This cluster of work presents or evaluates the proposed interaction techniques such as the use of gestures [16, 17, 24, 25, 27], voice command [24, 40], body movements [1, 2] and others [9, 14, 30] or the integration of several modalities at the same time [41, 42]. Other also investigated if some interaction techniques could be more intuitive than others [33, 44]. Even though some papers just provide a description of the system, with software and hardware specifications, other investigate how the proposed interaction technique is perceived by users and if it could be suitable in a real interaction scenario. Findings from this clusters also confirm, that combinations of different modalities such as voice commands, gestures, gaze direction, and body movements has the potential to further increase the intuitiveness of the interaction.

Human Preferences. Taking in consideration human preferences is advantageous. Studies investigating how humans wish to interact with drones have offered significant strengths that the HDI community should draw upon and seek to complement the findings found. This group of papers rely solely on a human-centered approach, investigating what humans desire from the drone technology, providing meaningful insights for what humans expect from drones. For example human preferences were the basis to investigate which interaction users decide to use when interacting with drones [24, 26], others aimed to find which gesture should be used when running with a drone [27] or investigated user requirements for a home drone companion [58]. Hence, investigate human-preferences may help to understand how humans perceive this technology and how to improve the critical aspects of it.

Social, Companion, Assistive computing. In recent years, drones have been gaining enormous popularity for many applications including using them in social contexts. A large number of studies tried to identify, which characteristic a social drone should have, and which aspects could influence the satisfaction in a social drone service. Research focused on identifying answers to question such as: *What role might the drone have?* [65] *What characteristics should drones as companions have?* [48, 65] *What kind of tasks would users expect a drone companion would do?* [58]. As can be noticed, apart from utilitarian purposes, researchers proposed to use drones as companion [58, 65, 72], moving them from functional use to being socially integrated. Another important aspect to be considered here is the social acceptability of drone technology for disabled, such as visually impaired people [67, 68], and those who face this technology in a social environment [75]. We therefore decided to group assistive, companion and social drones into one theme, since these studies focus on exploring how drones might support experiences of social interaction.

Intent, Approach, Feedback. One of the challenges that has been explored is how to communicate drones' intent to people. One may think of a direct speech communication [63,68,69]. However some considerations have to be taken into account. Speech can be expressed in different languages and is not always a desired modality (e.g. in a public space where a message is intended for one person only or a small group of people), and noise (from the environment and drone's propellers) can diminish its effectiveness. Therefore, different methods can be integrated into drones that can guarantee a good level of communication of a drone's intent [77, 83].

It has been acknowledged, that any potential misunderstanding of drones' intent can cause damage and reduce people's trust. While successfully understanding, for example, where and how the drone will fly may enhance understanding of its actions and increase collaboration with it. Furthermore, the way a drone approaches a person can significantly affect the way this technology is perceived during the interaction [47,50,54]. Adding feedback (lights, displays, voice and similar features) can highly increase the user experience, as humans can understand what the drone's intent or if the drone responds correctly to user's actions.

Intent, approach and feedback are thus grouped in one theme, since are all related to how a drone should behave in an interaction process.

Safety, Security, Privacy, Ethics and Culture. Three themes around human concerns were raised in relation to drones: safety, security and privacy. Nearly all studies covered concerns humans were facing when co-located with drone(s). The major one is safety, as the drone may damage and cause injuries if something goes wrong. As drones are nowadays equipped with other technologies, such as sensors and cameras, concerns about privacy violation and security were also an issue. Studies on safety, security and privacy focus on understanding which components influence them, and point out important aspects that should be considered when designing drone systems and guidelines to improve regulation and registration procedures.

Apart from safety, security and privacy, studies in drone technology also revolve around ethics and culture. It is understandable how can the use of a drone be influenced and influence the culture we live in and how can drones raise multiple ethical issues. We can observe that many studies researched and pointed out different human behaviour towards drones depending on the culture the studies were conducted in; this involved both the acceptance of drones on humans' behalf and the way people chose to interact. As it comes to ethics, the amount of ethical issues that emerged in their employment, can't be ignored. More specifically, studies focus on the question if it is ethical to use drones in several contexts and if culture influences the perception of which use of the drones is ethically acceptable.

8.2 Study Methods

Studies in our corpus of literature employed different methods to gather information. User studies unfold valuable insights about users' feelings, expectations, desires, and struggles. Interestingly, some of the literature covered is not user centered but focuses rather on the presentation of the prototype [20,22,41,94,114] without even conducting a user study. It is noteworthy to mention that user research keeps humans at the center of the design process and that to gather information about human a user center approach is necessary.

The research questions under investigation were evaluated with different approaches and data collection were collected through: surveys, questionnaires, interviews, focus groups, design workshops, field observations and field studies, wizard-of-oz techniques, and usability testings. Each of them has its advantages and disadvantages. For example, conducting field studies is advantageous to understand in person which interaction techniques participants choose when interacting with a drone. To gather knowledge about how humans perceive this novel technology and what do human expect from drones, a common approach is to conduct focus groups and interviews, or either online surveys and questionnaires. In addition to interviews and surveys, co-design workshops were also used in studies to understand human preferences of the physical aspect of drone to make it more acceptable.

Whereas some studies do not present user studies at all, other combine several methods to collect information from users, which certainly helps researchers to gain in-depth understanding of how human respond to a particular technology under the research question being investigated.

8.3 Environment

For user studies where a drone was used, different environments were chosen. We found three frequent choices where the various user studies took place:

(1) **Outdoor**: Participants interact with drone in an open-air space

(2) **Indoor**: Participants interact with the drone in a closed space

(3) **VR**: Participants are not directly interacting with a drone but through virtual reality environment or augmented environment

Malfunctions and other factors like weather conditions could compromise drone's behaviour and consequently the study process. In order to ensure a safe environment, many studies were conducted indoors, to better control the behaviour of a drone. However, if the drone is to be used outdoors the indoor environment can highly influence

Table 4: The list of study methods and papers using them.

Study method	**Reference (year)**
Concept only	[13, 115] (2015), [99, 116] (2016), [91, 104, 117, 118] (2017), [37, 52, 95] (2018) [119–122] (2019), [123] (2021)
Survey and Questionnaires	[2,17,46] (2013), [21,77] (2014), [71,83] (2015), [78,124,125] (2016), [8,55,58,62, 126] (2017), [27, 63, 79, 98] (2018), [60] (2019), [81] (2021)
Interviews	[46,51] (2013), [14,64,87] (2014), [24,67, 103] (2015), [65, 86, 97, 124, 127] (2016), [8, 48, 59, 73, 96] (2017), [9, 15, 75, 112, 128] (2018), [50,129,130] (2019), [25,61] (2020) [69, 131] (2021)
Focus groups and design workshops	[48,58] (2017), [112] (2018), [61] (2020) [69] (2021)
Indoor studies	[16] (2011), [2, 17, 46, 51] (2013), [14, 21, 34, 77] (2014), [67, 83, 132] (2015), [6,26,44,53,74,108] (2016), [48,59,133] (2017), [9, 15, 19, 75, 112, 134] (2018), [50,82] (2019), [69,114,135] (2020)
Field observations and studies	[18] (2011), [72] (2012), [64,87] (2014), [24,67,71] (2015), [78,84,86,124] (2016), [8, 48, 55, 59, 62, 73, 126, 136] (2017), [9, 27,49,63,75,79,112] (2018) [130] (2019), [25, 137], [131] (2021)
VR studies	[33] (2013), [77] (2014), [138] (2015), [92,125] (2016), [39,58,90] (2017), [128, 139, 140] (2018), [93] (2019)
Prototype only without user study	[20] (2013), [3–5, 85] (2014), [22, 41] (2015), [1, 12, 86, 89] (2016), [23, 88] (2017), [35, 52, 79, 95] (2018), [94] (2019), [38, 45, 114] (2020), [10, 141] (2021)

the results of a study, and consequently it moves it far from a real world scenario. Indoor environments makes sense if the drone is envisioned to be used in it, for example as a home companion. Outdoor environments allow to investigate remote interaction and co-located interactions with a drone. Several studies do not use a physical drone and the interaction is moved to environments such as virtual reality [93, 125, 141, 142], augmented reality [140] or even videos and computer games [77, 81, 138]. This provides a safe space for exploring human-drone interaction, however, the immersiveness in such environments compared to the real world is currently not on par.

8.4 Drone's autonomy

Progress in hardware and software technology and advancements of on board intelligence allow the development of drones capable of flying autonomously. The autonomy of drones plays an important role during the interaction process. While drones can be controlled by one person, the situations can emerge where the need of several people interacting and collaborating with drones is needed.

Several studies presented in this work have tried to identify how people behave when interacting with an autonomous drone. Three different options were tested. One of the most used methods is the wizard-of-oz, where the drone is presented as autonomous to participants, but is in fact controlled by a hidden controller [8, 39, 49]. Other studies used a pre-programmed flying pattern presenting the drone as flying and acting autonomously [50, 100]. Due to the fact that completely autonomous drones [10, 63] are highly unpredictable, only a few studies chose this option. To do so, some were conducted in indoor environments to prevent possible non desired behaviours of drones that could happen due to unexpected climate conditions or other factors that could turn out as dangerous [50, 143]. Others decided to control the drone behaviour by mounting the drone on the ceiling [46] or on a tripod [27]. Safety glass was also used to prevent possible collisions between humans and drones [48]. Many studies included a protective cage around drones [5, 8, 50, 142].

One of the questions researchers were trying to answer is whether humans are ready and willing to accept autonomous drones in their everyday lives, since concerns about the presence of drones, as seen in the previous chapter, are the main reason why people do not trust them. However, the autonomous drone was preferred over human controlled one where privacy/safety was in question [100], but in some studies users expressed that drones should not to be fully autonomous and should be guided by users [58, 65].

9 Conclusion

The use of drones has increasingly expanded in the last two decades. Their presence in our every day lives has opened a significant number of questions about how and if people are willing to accept the drones and interact with them. The researchers in the field of HDI tried and are still trying to answer different research questions that were discussed in this thesis.

This work provides an overview of research papers in the field of HDI and focuses on different aspects that should be considered to make the interaction between humans and drones as smooth and as intuitive as possible. Through this work we tried to schematise and categorise papers describing interaction techniques from and for drones, present the main findings and provide the most important themes that emerged during our analysis.

The first studies in the field mostly focused on interaction techniques between drones and humans. Later, after the idea of social drones took over, many researchers became interested in employment of social drones in the fabric of everyday life. The topic additionally shifts the attention on issues, revolving around the acceptance of such drones in a social context. Such articles' results are mostly based on questionnaires, focusing on the feelings of people towards social drones. Deeper analysis gave the participants a range of different possibilities from which to choose and answers clearly showed that concerns mostly come from lacking the knowledge of the vast number of possibilities drones drones can be used and ease everyday life.

We started this work by describing the interaction techniques proposed by HDI researchers and continued with the exploration of different parameters that influence the interaction. We then focused on the acceptance of drone technology in a social context and connected the topics together. The research included also how people want drones to convey their intent and which human concerns have been found around drones. Raising awareness on the multiple possibilities the employment of drones can offer, can help people feel more comfortable towards this technology, bring it closer to them, which could consequently help scientists to develop more effective interactions techniques.

10 Povzetek naloge v slovenskem jeziku

Droni ali brezpilotni letalniki, so tehnološke naprave, ki so bile prvotno zasnovane v vojaške namene. Ker se je v zadnjem desetletju ta tehnologija razširila tudi na različne druge vrste uporabe, je bila v družbi takoj zaznavna skrb v zvezi s težavami in nevarnostmi, do katerih uporaba dronov lako privede. Čeprav se razmišljanja posameznikov med sabo razlikujejo, je mogoče v le-teh zaslediti skupne točke, ki znanstvenikom služijo pri izoblikovanju novih strategij za izpostavljanje čim bolj prijetnejše in intuitivne interakcije med dronom in človekom. Z namenom razvrstiti omenjene strategije in zaznane težave, ki tako z vidika delovanja drona kot z vidika njihovega zaznavanja s strani človeka vplivajo na nemoteno sobivanje, smo zbrali literaturo, ki analizira vse te dejavnike. Kategorizirali smo smernice in rezultate več kot sto člankov in jih shematsko predstavili v tej nalogi. Spoznali smo, kako se človek odziva na drone na podlagi kulturnih in okoljskih dejavnikov ter seveda na podlagi tehnik, s katerimi dron s človekom komunicira. Prav tako smo razvrstili tehnike, s katerimi dron vzpostavlja stik s človekom.

V tretjem poglavju smo se osredotočili na tehnike interakcije med človekom in dronom, ki slonijo na spoznanjih iz področja robotike, bolj specifično, odnosu med človekom in robotom. Predstavili smo vrsto znanstvenih člankov, ki orišejo doslej raziskane metode, s katerimi lahko človek upravlja drona oziroma z njim komunicira. To so na primer gibanje glave, telesa, pogled, dotik, kretnje, verbalna komunikacija, možgansko-računalniški vmesniki in multimodalnost. Človek dandanes v splošnem ni še pripravljen popolnoma sprejeti te tehnologije, zato je del naloge posvečen ravno parametrom, ki jih človek aplicira pri določanju stopnje (ne)varnosti, ki mu jo uporaba drona v določeni situaciji vzbuja. Spoznali smo dejavnike, ki vplivajo na sprejemanje dronov in kako se človek odziva med interakcijo z njimi. Videli smo, pod katerimi pogoji poteka interakcija nemoteno in prijetno, kdaj jo človek brez težav sprejema, kako se lahko izognemo negativnim predstavam in kolikšno stopnjo avtonomije lahko prevzema dron.

V prvi fazi našega raziskovanja smo spoznali splošne značilnosti, ki vplivajo na interakcijo: bližina, pot, hitrost, višina in druge. Pozornost smo posvetili tudi k značilnostim izgleda drona, kot so na primer barva, oblika, izgled in druge. Del naloge smo namenili tudi študijam, ki se osredotočajo na načine podajanja namena drona človeku – spoznali smo, kako se človek odziva na različne poti, ki jih dron preleti, na glas, ki je v dronu integriran in na "obrazne značilnosti". Ker ne gre zanemariti strahu in nezaupanja, ki ju ta tehnologija vzbuja v človeku, smo razvrstili najpogostejše vzroke zaskrbljenosti v povezavi z droni: varstvo zasebnih podatkov, varnost, kršitev etičnih vrednot in kulturne razlike. Naša naloga je obenem zaobjela možnosti, ki jih uporaba dronov lahko prinese, s predstavitvijo nekaterih aplikacij, kjer so droni lahko nepogrešljivi. Med temi gre omeniti dostavo dobrin, medicinskih pripomočkov in drugega, pomoč invalidnim osebam, podporo športnim aktivnostim in drugim dejavnostim. Zaključili smo z opisom šestih poglavitnih tem, ki smo jih izluščili iz literature in njihovo prekrivanje z obstoječimi načini interakcije.

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