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Robots as Human Companions: A Review

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Completed Research Paper

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Abstract

The field of robotics has grown exponentially over the years, especially the social aspect has been given a lot of attention. Although there is a significant amount of research on robots being used as social human companions, there is a lack of a comprehensive study. The lack of knowledge includes the types of robots used, their features, interaction modalities and deployment scenarios. To address this knowledge gap, we have conducted a systematic literature review of 98 relevant articles. The findings suggest that anthropomorphic and zoomorphic robots are more popular as human companions while there is a lack of interest in functional and caricatured robots. Also, human-like and animal-like features are implemented more in them. A lack of utilizing the mobility of robots can be seen in the research and thus outdoor implementation of companion robots is seen very rarely. Moreover, the understanding of human-robot companionship needs a clearer definition.

Keywords: Companionship, Human-robot interaction, Companion robots

Introduction

In recent times, robotics technology has been one of the most rapidly growing sectors which is on the verge of revolutionizing many aspects of living. According to GlobalData Thematic Research (“Robotics Growth Is about More than Technology” 2021), the robotics industry will surpass the $500bn mark in 2030 which was just $45bn in 2020. Nowadays, robots are used in many domains such as manufacturing (Cherubini et al. 2016), logistics (Acosta Calderon et al. 2015), healthcare (Shibata and Wada 2011), education (Belpaeme et al. 2018), entertainment (Manzotti and Tagliasco 2005), rehabilitation (Huo et al. 2016), agriculture (Neves 2018), military (Jentsch 2016) and customer service (barakeh et al. 2019).

Companionship can be defined as the phenomena of having someone or something as a friend or companion in different times and situations, creating a sense of fellowship in the process (Beck and Katcher 1996; Buhrmester and Furman 1987). Social features (Hameed et al. 2016), as well as proper embodiment (Wang and Rau 2019), can create meaningful interactions between humans and robots, making them suitable to be used as companions. This points to social features, defined embodiment and meaningful interaction through various modalities can lead to companionship. The definition of companionship leaves room for non-human creatures and non-living things to become human companions. This also requires defining the companionship between humans and non-humans, such as robots in this study. Robot companions can be defined as robots capable of performing various tasks through their ability to interact physically, socially, emotionally, and safely with humans (Dario et al. 2011). Robots have been employed as companions or collaborators for humans, especially in social interaction contexts. They have been given the role of healthcare assistants (Robinson et al. 2014), companions for people with dementia (Chen et al. 2020), gait rehabilitation assistants (Lee et al. 2020), reading companions (Joseph E. Michaelis and Mutlu 2018), exercise coach (Schneider and Kümmert 2016), music and video listening companions (Hoffman et al. 2016) and shopping assistants (Bertacchini et al. 2017). Considering robots are deployed in many scenarios with humans, understanding the socio-technical aspects (Baxter and Sommerville 2011) are very important to understand the relationship as well as information flow. It would also be helpful to understand this relationship through task-technology fit (Andersone et al. 2021) theory to quantify their effectiveness.

Human-robot interaction (HRI) (Goodrich and Schultz 2008) has been a very prominent field in human-computer interaction (HCI) (Dix et al. 2004) research. Robotics technology is improving every day and robots are being introduced in different new domains and scenarios. To understand how robots should be designed for specific scenarios, it's important to understand what types of robots have been already used in them, what features they have and what modalities they use to interact. In this study, we want to investigate robots that have been used in companionship scenarios. We aim to understand the robot types, their features as well as their interaction modalities. There is a lack of a comprehensive study that gives a proper overview of robots that have been used as companions, their usage scenarios, usage domains as well as purpose. Also, there is a lack of knowledge in terms of the types of robots used for creating companionship, their characteristics, appearance, features, and interaction modalities. This article aims to address this knowledge gap through a systematic literature review. We contribute to the field of human-robot interaction by answering the following research questions.

- What types of robots or robotic applications have been investigated in the corpus of human-robot companionship?
- What are the domains and facilities in which human-robot companionship has been investigated?
- What features and interaction modalities have been used in companion robots?

Method

Search Strategy

To obtain relevant literature, a search string was created with a view to covering all the key aspects of human-robot companionship. We were specifically interested in companionship with robots and wanted to cover all relevant literature on robot companionship. As a result, we did not limit the search to any keyword other than "robot" and "companion". The Scopus database was queried with the following search string:

TITLE-ABS-KEY (robot* AND companion*) AND (LIMIT-TO (DOCTYPE, "cp") OR LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "ch")) AND (LIMIT-TO (LANGUAGE, "English"))

This query was performed on 16 July 2021 and returned 1731 documents. The search scope was limited to conference papers, journal articles and book chapters. Literature only in the English language was considered in the process.

Review Procedure

The process of obtaining the final list of articles for analysis consisted of several phases. The whole screening process flow is shown in Fgure 1. At first, all 1731 articles were compiled into an Excel file which included information like title, publication avenue, publication year, keywords and abstracts. The files were checked for duplicates and a total of 12 articles were removed as a result. The resultant 1719 articles were then screened using their title and abstract according to a defined exclusion criterion, excluding 1376 articles. The remaining 343 articles were included for further analysis. We excluded papers that are not peer reviewed, does not focus on human-robot companionship (HRC), its creation (scenarios, influencing factors, interaction types and modalities), effects (social, psychological) and roles. Also, studies around virtual robots were excluded.

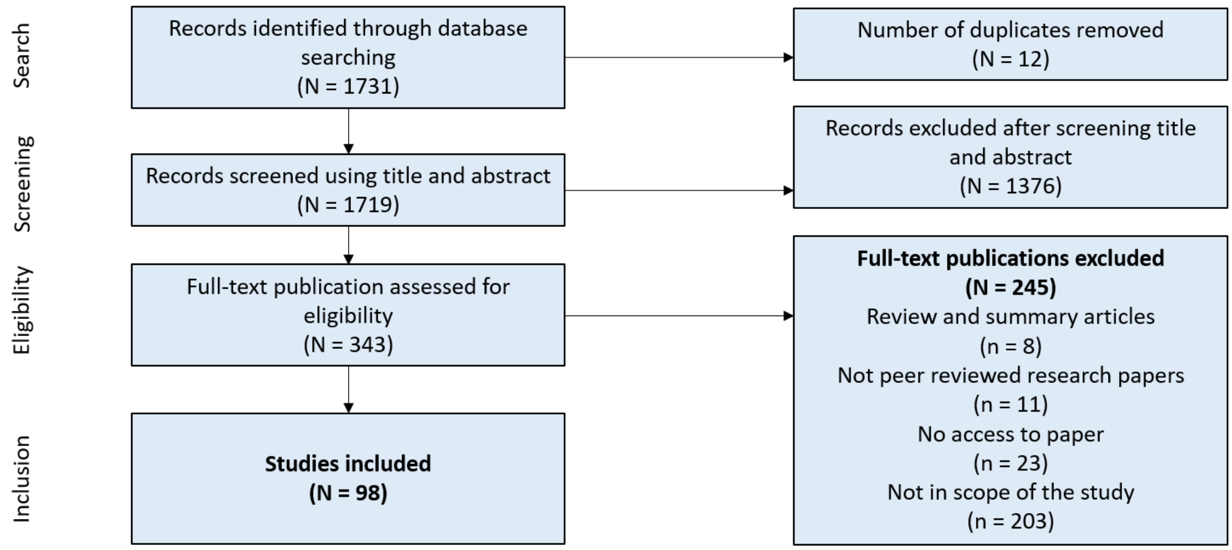

Figure 1: Flow Diagram of the Screening Process.

23 out of the 343 articles were inaccessible through online databases. We contacted the authors of these articles through email and ResearchGate but none of them responded in time for them to be included in further analysis. An additional 222 articles were excluded after going through the full texts. 8 of them were review or summary articles, 11 of them were not peer reviewed and the rest 203 were deemed out of scope of this review based on the exclusion criteria. 16 out of the 203 out of scope articles were excluded during the final coding phase. After this, we were left with a total of 98 articles that were used for information extraction and analysis. During the coding phase, information was extracted on the domain areas of use, purpose, deployment facility and scenarios, robots used as well as their features and interaction modalities.

Findings

Publication Year

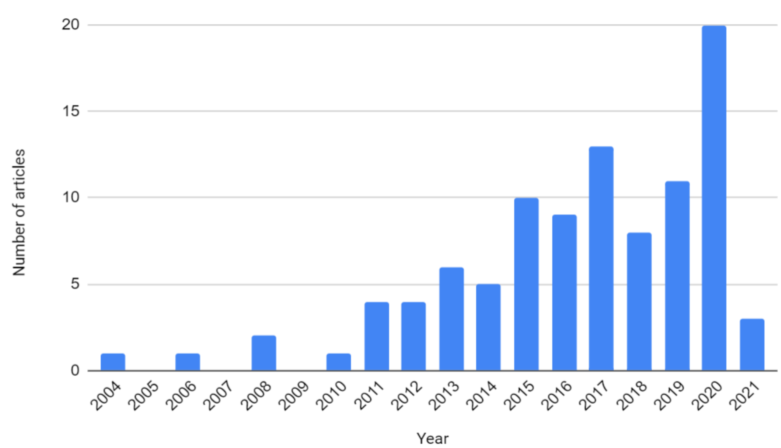

Figure 2: Year-wise Published Number of Articles.

Figure 2 demonstrates the number of articles published each year on human-robot companionship, starting from 2004. During the years 2004 to 2010, there were some scattered efforts to explore the topic. Starting from 2011, there has been a significant increase in the number of publications. In 2020, the number of publications almost doubled compared to the previous year which can be interpreted as an increase in interest and possibilities around the topic. As the corpus was collected on July 16, 2021, majority of the related works of that year were not published or accessible yet, hence the low number of publications in the year of 2021.

Publication Avenue

Out of the 98 finally selected publications, 35 were journal articles, 49 conference papers and 14 book chapters which accounted for 35.72%, 50% and 14.28% of all the articles respectively. The 98 publications belong to 54 unique venues. Popular venues were Lecture Notes in Computer Science (11 entries), International Conference on Human-Robot Interaction (HRI) (7 entries), ACM CHI Conference (7 entries), International Conference on Robot and Human Interactive Communication (RO-MAN) (6 entries), International Journal of Social Robotics (5 entries), IEEE International Conference on Robotics and Automation (4 entries) and Journal of the American Medical Directors Association (3 entries). International Conference on Human-Agent Interaction (HAI), International Conference on Multimodal Interaction (ICMI), Applied Sciences (Switzerland), International Conference on Humanoid Robotics (Humanoids), Australasian journal on ageing and International Conference on Intelligent Robots and Systems (IROS) all had 2 entries each. All other venues had 1 paper each in the corpus.

Domain Areas

The list of domain areas in which robots have been employed as companions is demonstrated in Table 1. Note that some of the studies seem to belong to multiple domains, however, the domain area categorization here has been performed on the basis of the purpose of the robot.

Domain	**References**	**N**	**%**
Wellbeing	(Biswas and Murray 2015; Bradwell et al. 2020; Edwards et al. 2020; Engler et al. 2018; Gross et al. 2019; Hirokawa and Suzuki 2018; Ihamäki and Heljakka 2021; Jeong et al. 2020; Joglekar and Kulkarni 2018; Khosla and Chu 2013; Lu et al. 2011; Moyle et al. 2016; Robinson et al. 2013, 2015; Shamsuddin et al. 2017; Zhang et al. 2020)	16	16.32
Education	(Ab Aziz and Ghanimi 2020; Axelsson et al. 2019; Bautista et al. n.d.; Chu et al. 2019; Degiorgi et al. 2017; Gordon et al. n.d.; Hsiao et al. 2015; Marti and Iacono n.d.; Michaelis and Mutlu 2018 a; Michaelis and Mutlu 2018 b; Michaelis and Mutlu 2017; Su et al. 2008; Uluer et al. 2015; Westlund and Breazeal 2015; Yueh et al. 2020)	15	15.31
Socialization	(Biswas and Murray 2015; Casey et al. 2020; Döring et al. 2016; Garrell and Sanfeliu 2012; Khot et al. 2019; Mancini et al. 2020; Passler Bates and Young 2020; Repiso, Anais Garrell, et al. 2020; Repiso, Anaís Garrell, et al. 2020; Robinson et al. 2016; Sarabia et al. 2018; Tsiourti et al. 2020)	12	12.24
Healthcare	(Abdollahi et al. 2017; Broadbent et al. 2014; Chen et al. 2020; Gross et al. 2015; Kidd et al. 2006; Law et al. 2019; Liang et al. 2017; Orejana et al. 2015; Pike et al. 2021; Ritschel et al. 2019; Thunberg et al. 2020)	11	11.23
Disability Assistance	(Arnold 2016; Bakracheva et al. 2020; Fisicaro et al. 2019, 2019; Garzotto et al. 2017; Gross et al. 2012; Lehmann et al. 2011, 2014; Schroeter et al. 2013; Soleiman et al. 2014; Ullrich et al. 2016)	11	11.23
Motivations and Influence	(Bertacchini et al. 2017; Fasola and Mataric 2012; Gallagher et al. 2020; de Graaf and Allouch 2017; Graether and Mueller 2012; Kahn et al. 2004; Menezes and Rocha 2021; Mueller and Muirhead 2015; Schneider and Kümmert 2016; Schneider and Kummert 2016)	10	10.21
Rehabilitation	(Casas et al. 2019; Gross et al. 2017; Hebesberger et al. 2016; Kohori et al. 2018; Lee et al. 2020; Meyer and Fricke 2017; Okita 2013; Randall et al. 2019)	8	8.15

Entertainment	(Hansika et al. 2020; Hirose et al. 2014; Hoffman et al. 2016; Hoffman and Vanunu 2013; Hosseini et al. 2017; Leite et al. 2010; Leite and Castellano 2012)	7	7.14
Navigation and Guidance	(Acosta Calderon et al. 2008; Clotet et al. 2014; Piezzo and Suzuki 2017; Rossi et al. 2019; Sarabia and Demiris 2013)	5	5.11
Assistance	(McGinn et al. 2019; Sundar et al. 2017; Zsiga et al. 2018)	3	3.06
Total		98	100

Table 1: Domain Areas of Selected Corpus.

The most popular domain area for exploring the companionship between humans and robots is wellbeing. Studies have focused on understanding how robotic companions can make lives easier for users through psychological support (Jeong et al. 2020; Robinson et al. 2013), emotional support (Gross et al. 2019; Khosla and Chu 2013), stress reduction (Edwards et al. 2020; Engler et al. 2018), break taking during long working hours (Zhang et al. 2020), and depression management (Shamsuddin et al. 2017). Robots have also been deployed as companions in supported living facilities to reduce depression (Bradwell et al. 2020).

Education is another domain that has been explored very frequently in terms of robotic companions. A majority of these studies have investigated different reading activities in presence of the robot while the robot acts as either a motivator or mediator of users' reading behavior (Chu et al. 2019; Degiorgi et al. 2017; Marti and Iacono n.d.; Michaelis and Mutlu 2017; Yueh et al. 2020). In other studies, robots have been given the role of peer tutor for mathematical problem solving (Bautista et al. n.d.), tutor of second language (Gordon et al. n.d.) and language teachers for children (Hsiao et al. 2015). In addition to these, robots have been deployed as sign language tutors for kids (Uluer et al. 2015) as well as children with autism spectrum disorder (ASD) (Axelsson et al. 2019).

There are a significant number of studies where robots have been used to promote or facilitate socialization. Robots have been studied as companion for reducing loneliness (Casey et al. 2020; Passler Bates and Young 2020; Robinson et al. 2016), combating social isolation (Sarabia et al. 2018; Tsiourti et al. 2020), facilitating outdoor socialization (Garrell and Sanfeliu 2012; Repiso, Anais Garrell, et al. 2020; Repiso, Anaís Garrell, et al. 2020) and promoting social interaction in elderly (Döring et al. 2016). They have also been deployed as commensal or dining companions (Khot et al. 2019; Mancini et al. 2020).

Healthcare and disability assistance domains have been explored quite extensively. The majority of the studies in the healthcare domain focus on the effects of robotic companionship on people with dementia (Abdollahi et al. 2017; Chen et al. 2020; Law et al. 2019; Pike et al. 2021; Thunberg et al. 2020). Domestic health assistance (Gross et al. 2015; Ritschel et al. 2019) and medication adherence through companion robots have also been investigated (Broadbent et al. 2014). Robotics companions have been introduced in lives of people with disabilities, such as for children with ASD (Bakracheva et al. 2020; Mayadunne et al. 2020), people with neurodevelopmental Disorder (NDD) (Fisicaro et al. 2019; Garzotto et al. 2017), children with anxiety (Arnold 2016) and down syndrome (Lehmann et al. 2014).

Robotic companions have been used as motivational agents in different situations, such as exercising (Fasola and Mataric 2012; Menezes and Rocha 2021; Schneider and Kümmert 2016) and jogging (Graether and Mueller 2012; Mueller and Muirhead 2015). The influence of companions has also been explored on choice of food (Gallagher et al. 2020), shopping behavior (Bertacchini et al. 2017) and sustaining longer on different tasks (Schneider and Kummert 2016).

Other areas where robotic companions have been introduced less frequently are rehabilitation, entertainment, navigation, guidance, and assistance. Robots have been used in stroke rehabilitation therapy (Casas et al. 2019; Meyer and Fricke 2017), gait rehabilitation (Lee et al. 2020), therapeutic support for people with dementia (Hebesberger et al. 2016) and walking training (Gross et al. 2017). In terms of entertainment, robots have been used as music listening (Hansika et al. 2020; Hoffman and Vanunu 2013) and video watching companions (Hoffman et al. 2016). In addition to that, robotic gaming companions (Hirose et al. 2014; Hosseini et al. 2017; Leite et al. 2010; Leite and Castellano 2012) have also been explored. There have been several studies where robots have been introduced as walking companions both indoor (Piezzo and Suzuki 2017) and outdoor (Sarabia and Demiris 2013). Navigation guidance through robots (Acosta Calderon et al. 2008; Clotet et al. 2014) have been extensively explored in these studies. In the assistance area, robots have been deployed to assist humans in a socially active way in homes (Sundar et al. 2017; Zsiga et al. 2018) and care facilities (McGinn et al. 2019).

Types of Robots Used

A total of 69 different robots have been used to investigate companionship in the selected corpus. Here, they have been categorized based on the categorization proposed by (Fong et al. 2003). Table 2 specifies the robots used as well as their mobility. We can see that almost half of the robots used were anthropomorphic and a significant number of zoomorphic ones. This indicates that human-like or animal-like robots are thought to be more suitable for companionship. Data demonstrates that a major section of the anthropomorphic and functional robots happen to be mobile while zoomorphic and caricatured ones are mostly stationary or not mobile. We can also see that there are some very popular choices of robots when it comes to researching human-robot companionship, such as Nao robot has been used in 10 studies, Paro has been used in 8 studies and Joy for All animal robots have been used a total of 7 times. However, the use of 69 robots also suggests a lot of variety in the research domain.

Robot Type	Robots	Mobility	N
Anthropomorphic	GrowMu social robot, Vi, Mario, Kabochan, Julia, Tibi (3), Dabo (2), myKeepon (2), AudiMO, Education Companion Robot, Nao (10), InMoov, Silbot, Stevie, Pepper (2), Kompai, Minnie (3), Ryan companionbot, Puffy (2), Darwin, ROREAS (2), SCITOS G5, Erwin, Max, Robovie R3, Dragonbot, SCITOS G3 (2), Bandit, iRobi, iRobiQ (2), Cafero, Kaspar (2), Matilda, CompanionAble, Robbie	Mobile (21) Not mobile (14)	35
Zoomorphic	Ageless Innovation/Joy for all Cat (4), Joy for All Robot dog (4), Snugglebot, Assistive robotic companion, SYMPARTNER, ELE, Paro (8), Pleo (3), Romibo, Interactive therapy robot, Emobie, Tega, Cuddler, RoboParrot, iCat (2), Karotz robot, Aibo	Mobile (4) Not mobile (14)	18
Functional	Anki Vector robot, Anki Cozmo robot, ROBOCO, IQRA, Robotic Haptic Force System, HomeMate robot, Jogging companipn drone, Outdoor robotic companion, IROMEC (3), Joggobot, mediRobbi	Mobile (9) Not mobile (2)	11
Caricatured	FoBo (2), Jibo, Social robotic companion, Pepita, Travis (2)	Mobile (1) Not mobile (4)	5
Total			69

Table 2: Types of Robots Used.

Deployment Facilities

Robotic companions have been deployed in different domain areas for different purposes which has led to them being used in different scenarios and facilities. Table 3 demonstrates the deployment facilities where robots have been used as companions. Companion robots have been used most frequently in home or domestic facilities. Out of 76 reported facilities in the selected corpus, 22 were home environments. Aged living/care facilities such as residential care facility, long term care facility, rehabilitation centers and elderly care facilities have been frequenting in companion robot deployment. Educational institutions are also popular for this kind of deployment. Companion robots being used a lot for healthcare and wellbeing purposes justify the use in care facilities while education institution facilities suggest the interest and focus on research. Healthcare centers are also a popular facility for such kinds of deployments. Among other facilities, there are some outdoor field implementations as well as in some occupational facilities.

Facility Type	Facility	N
Home/Domestic facility		22

Aged living/care facility	Residential Care facility (6), Long term care facility (2), Rehabilitation center (3), Retirement village (1), Old-age home (1), Dementia Day care center (1), Aged/Elderly care facility (3)	17
Educational institution	School (7), Special education school (2), Library (2), University dormitory (1), University campus (4)	16
Healthcare center	Therapy center (2), Nursing home (1), Hospital/Clinic (6)	9
Outdoor	Outdoor street (3), Outdoor field (1)	4
Office/Occupational facility		3
Other	Chocolate testing facility (1), Robotics development facility (1), Isolation dome (1)	3
Activity center/club	Day Activity Center (1), Club for people with disabilities (1)	2
Total		76

Table 3: Deployment Facilities.

Robot Features

Table 4 demonstrates which features and functionalities have been implemented on robots and in what frequency to create human-robot companionship. According to the list of features, we have divided them into categories like verbal, non-verbal, expressive, personalization, functional, navigation and other features through inductive coding (Thomas 2006). Use of voice, sound and some sort of verbal communication functionalities have been used very frequently. In terms of non-verbal features, movement of body parts has been the mostly used feature. We can also see a good amount of usage of expressive features consisting of facial and emotional expressions. These verbal, non-verbal and expressive features are also very common in humans and thus suggesting human-like features have been explored more.

Category	**Features**
Verbal	Voice (28), Sound (17), Verbal communication/conversation (7)
Non-verbal	Movement of body parts (35), Haptic feedback (4), Gestures (2),
Expressive	Emotional expression (10), Facial expressions (10)
Personalization	Mood/emotion recognition (2), People tracking/recognition (6), Song suggestions (2)
Functional	Touchscreen (14), Image projection (1)
Navigation	Navigation/Movement (17), Path mapping/Following (4), Following user (2)
Other	Interactive games (2), Memory assistance (2)

Table 4: Robot Features.

Personalization features have also been explored, such as emotion recognition, song suggestions and person recognition and tracking which allow the robot to provide personalized interaction and output to the user. However, these have not been explored extensively. Touchscreen interaction as a functional feature has been explored significantly. Although this requires a touch enabled display or tablet, this mode of interaction with robots is easy to implement and easy to use. As half of the robots are mobile, navigation, path planning and following are quite common features of these robots. Lastly, there are interactive games and memory assistance as other features that have been added to robots.

Interaction Modalities

Different interaction modalities and techniques have been tested on different robotic companions for creating meaningful interactions between humans and robots. Table 5 lists all the interaction modalities used in the selected corpus, divided between input and output modalities. For both input and output, voice is the most popular modality while sounds have also been used quite frequently. Touchscreen displays are another modality that has been used a lot and belongs to both input and output categories. The reason could be that attaching and connecting a touch display to a robot is easier than implementing complex features. This also allows the user to have a well-defined interaction method which is self-explanatory and easy to use. It can be seen as a trend that functional features that are easy to implement and self-explanatory have been adopted in most scenarios rather than more natural modes. Also, the communication between humans and robots seems to be limited to giving commands and receiving some kind of feedback accordingly. This contradicts the fact that robots were meant to be deployed as companions to humans, not only an entity that obeys commands like maids.

Some of the robots take video data as input which calls for deeper analysis and better personalization features such as emotion or person recognition and then actuation based on that. Touching and handling the robot in different ways have also been introduced significantly, such as hugging, shaking, patting, squeezing, pushing and snuggling. These modalities imitate how humans usually interact with animal companions.

As output modalities, similar to the input modalities, voice, display and sound are largely popular. Apart from them, different types of gestures as well as movement of body parts are very popular which also imitate human and animal characteristics. Use of LEDs has been frequented to show emotions as well as expressions. Animal-like output modes can also be seen, such as purring, limping, frowning and tail flipping.

Mode	**Interaction**
Input	Voice (43), Touchscreen (19), Touch (15), Video feed (10), Sound (7), Striking (5), Remote control (4), Camera feed (3), Hug (3), Music (2), Facial Expression (2), Gestures (2), Smartphone (2), Patting (2), Hit (2), Squeeze, Joystick, Snuggle, Buttons, Push, RFID, Shaking
Output	Voice (29), Display (21), Sound (19), Gestures (16), LEDs (12), Head movement/Nodding /Shaking (11), Movement (9), Eye movement (7), Facial expression (6), Expression with eyes (5), Hand/Finger movement (4), Navigation (3), Gaze (2), Purring (2), Crying (2), Dance (2), Heartbeat (2), Movement of ears (2), Nodding (2), Haptic feedback, Limp, Frown, Smile, Emotional expression, Force, Projected image, Jump, Color projection, Change color, Flip tail, Song changing

Table 5: Interaction Modalities.

Discussion

Companion robots have been used in mainly wellbeing while outdoor implementations are scarce.

This study was conducted to gather comprehensive knowledge on robots that have been used or employed as human companions in different scenarios. The data suggest that robots have been deployed in many domains such as wellbeing, education, healthcare, assistance and socialization. This denotes the variety of scenarios where robots can be used as companions. One trend that can be observed here is that, so far robots have been used as companions in mostly wellbeing and healthcare or in similar domains. In an age where many households already have autonomous robots (e.g., robot vacuum cleaners) (Asafa et al. 2018; Orejana et al. 2015; Tarazón et al. 2019), more exploration is needed on how robotic companions interact with humans in other contexts, e.g., indoor, outdoor, day-to-day companionship, nature exploration. A minor difference can be seen in the types of robots in terms of their deployment in different scenarios. As example, functional robots are used more in physical activity and outdoor settings (Graether and Mueller 2012; Meyer and Fricke 2017; Mueller and Muirhead 2015), zoomorphic robots are more frequently used in elderly care settings (Ihamäki and Heljakka 2021; Robinson et al. 2016) while anthropomorphic robots are used more in social situations (Casas et al. 2019; McGinn et al. 2019; Rossi et al. 2019). Also, the deployment facilities indicate that robots are mostly used as companions in domestic or indoor settings. This could be the result of robotic technology being extremely prone to errors and it is risky to take them outdoors while being safe and effective (Rubio et al. 2019; Siegwart et al. 2011). Another shortcoming of the technology might be that robots that are mobile cannot still navigate on unusual and uneven terrains, making them not suitable for outdoor implementations. (Biswal and Mohanty 2021) This is also supported by the fact that half of the robots used in the literature are mobile but have rarely been used outdoors.

Anthropomorphic and zoomorphic robots have been used more frequently.

From the robot types, features and interaction modalities, it is evident that human-like and animal-like robots and features are adapted by the majority. Many of the robots try to imitate human or animal-like behaviors, features and interactions such as verbal and non-verbal behaviors. Also, animal specific interaction modes such as touching, hugging and patting. are seen quite frequently. This suggests that anthropomorphic and zoomorphic robots are more frequently used as companions and the current knowledge trend considers human-like and animal-like appearances to be more suitable as non-human companions. Although there are some works where functional or object-like robots have been introduced (Hirokawa and Suzuki 2018; Khot et al. 2019), they are not very frequent. Investigating how functional looking and caricatured robots can create the sense of companionship by investigating what features and behavior apart from appearance can affect the companionship factor between humans and robots is needed and calls for increased amount of research on features and behavior regarding companionship of robots.

Natural modalities are used indoors while outdoor settings require control through commands.

It can be seen that well-defined and self-explanatory interaction methods such as display, touch and voice commands have been used most frequently. A difference in interaction modes can be seen for different deployment facilities, especially between indoors and outdoors. Most of the interaction modalities mentioned in this study have been applicable for indoor settings. For outdoor settings, the robots are less autonomous and thus need to be controlled through wireless controllers through commands. Natural interaction modes such as voice, sound and touch are not seen in such scenarios.

Giving commands and receiving feedback seems to be the common interaction type while co-existence and co-performance related interactions are lacking.

Some natural interaction methods and scenarios like gaze and co-existence have been relatively underexplored. Here, co-existence means the natural process when two entities stay in the same place and acknowledge each other's existence. There is also a lack of more complex and thoughtfully programmed interactions such as context-aware conversations, voice and facial recognition and mood recognition. This leads us to conduct a deeper analysis on how features and interaction modes can be configured to create more natural experiences of companionship. Also, the interaction modalities used indicated that they are heavily oriented to provide communication between humans and robots that focus on giving commands and receiving feedback accordingly. However, the concept of companionship might expect interactions that might facilitate co-performance (Kuijer and Giaccardi 2018) rather than positioning robots as entities that obey commands like maids. This fact also puts a question mark on the perceived meaning of companionship with robots. From the purpose of the studies, at times it is hard to infer if the robots are meant to be companions or just another order following agent that humans can control.

Human-like features are commonly used for creating meaningful interactions.

From the analysis of robot types, their appearances, features and interaction modalities, we can see that they comply with the definition of companionship which suggests that these factors if implemented properly can create companionship between humans and robots. According to our analysis, anthropomorphic and zoomorphic appearances are more familiar to humans, thus they have been used more frequently in companionship scenarios. Human-like and social features have been seen in all the robots that have been used in companionship scenarios, supporting the definition of human-robot companionship. In addition to that, all the natural interaction modalities used or recognized by humans such as voice, touch and sound were very frequently used to create the interactions meaningful to humans. This supports the fact that meaningful interaction is an integral part of human-robot companionship. In addition to understanding the effects of these factors, it's also important to understand how these factors can shape the relationship between humans and robots, how they make the interactions more meaningful and what different degrees of these factors can affect the relationship differently.

Distinct facets of human-robot companionship are needed to be discussed with more in-depth analysis and proper understanding of companionship is needed as well.

Overall, the study provides a comprehensive set of information on robots that have been used as companions. The types of interactions suggest a more commanding and obeying relationship between humans and robots which contradicts with companionship and needs to be defined more carefully. It is very important to define the roles of a robot when considered as a companion as command following machines cannot be autonomous while companions are supposed to be. In some cases, it is unclear what makes a robot a companion in some literature. There are many articles that have employed similar robots in similar scenarios as assistive or social robots but have not been touted as companions. It indicates that a clearer view is needed of what a companion robot is and in which scenarios. There are some other areas of concern, such as the lack of robot usage outdoors and in domains other than healthcare and wellbeing. Findings also denote the lack in use of functional and caricatured robots. This study has focused on the robots that have been used as companions or in companionship scenarios rather than focusing on the companionship itself. A more in-depth study has already been planned that will analyze the companionship factors such as the creation of companionship, relations between robot features and the degree of companionship and effects of different features on the type of companionship. We would also like to discuss further if different scenarios suit different types of robots for companionship. It will be also helpful to correlate the robot related information with each other as well as companionship factors to find the distinct facets of human robot companionship. In the process, it will be important to understand the dynamics and nature of the relationship between humans and robots. In addition to that, we should also be able to answer questions such as how this relationship is defines and how it shapes the life of humans.

Conclusion

This study reports a systematic review of 98 peer-reviewed articles to understand how robots have been used as human companions as well as their usage scenarios, features and interaction modalities. Major finding from the study is that robots with human-like and animal-like features have been used more frequently for companionship scenarios. Some future research directions were drawn, which includes implementation of outdoor robotic companions by improving the degree of mobility of the robots. Further research might be helpful to understand how functional and caricatured robots can be introduced more to this domain which will create diversity and new possibilities. In addition to that, more in depth research can be done to find out the distinct facets of human-robot companionship by finding the relationship between different robot features, appearance in terms of different domains and companionship scenarios.

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