An Interdependence Frame for (Semi) Autonomous Robots: The Case of Mobile Robotic Telepresence

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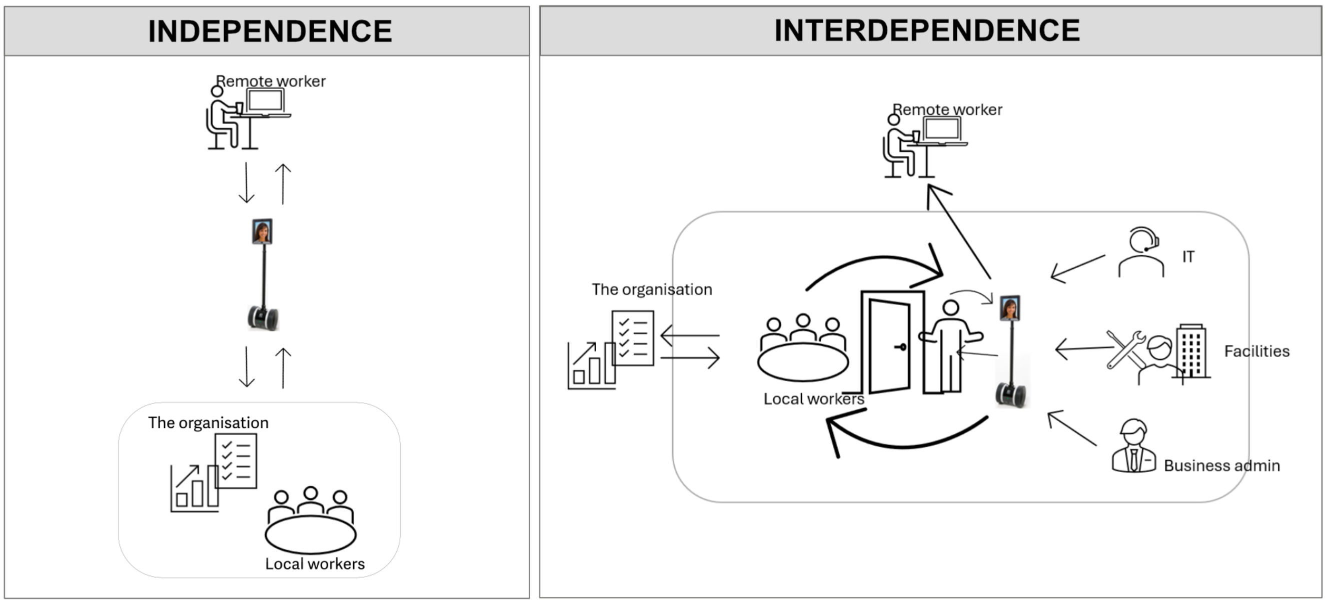

Figure 1: Mobile Robotic Telepresence applied in a workplace context, seen from different perspectives (independence and interdependence)

ABSTRACT

Technological advancements often promise to alleviate our reliance on one another through automating assistance. One such example is Mobile Robotic telePresence (MRP), which gives users the ability to move independently, whilst having a video call, by teleoperating a semi-autonomous robotic device. In this paper, we draw on the Interdependence frame for Assistive Technologies (AT), to question the underlying notion that technological improvements and the implementation of automation can truly create independent users. Applying the tenets of Interdependence onto a case study of MRP use, we unravel the many interdependent relations that exist between direct users and various other supporting individuals. In doing so, we provide an example of how the frame of Interdependance can be applied outside of AT studies, to inspire more critical research on automated systems, taking into account the unavoidable reality that all people rely on one another.

CCS CONCEPTS

• **Human-centered computing** → **Collaborative and social computing theory, concepts and paradigms**; **HCI theory, concepts and models**.

KEYWORDS

automation, videoconferencing, teleoperation, case study, assistance

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1 MOTIVATION & CONTEXT

Mobile Robotic telePresence (MRP) is often marketed as a solution to hybrid challenges because it allows a remote user to freely, "independently", move in space, thus granting them more autonomy than if they were bound to a non-mobile, traditional video-conferencing screen. This allows for a wider range of tasks to be done remotely, such as looking after older adults in their homes [36, 46], visiting museums [2, 47] and supervising medical training [14, 42]. MRP is also often presented as an avenue for accessibility, as it allows people to access a space without having to physically travel there. Examples include attending conferences [16], going to school [1, 43] and even working at a cafe [3, 45]. Still, a review of MRP by Zhang and Hansen (2022) highlights that considerations of universal access and of the safety of people co-located with of the robot are still missing from telepresence design. They also note that whilst features of automation might assist users in tele-operating the robots, lack of user control and lack of trust in automation might have the opposite effect.

Automation in MRP can take various forms. The current Double 3 model by Double robotics includes some semi-autonomous driving through waypoint navigation (the user selects a point in their view and the robot drives there by itself), collision avoidance (through Lidar) and autonomous parking into the charging dock. The Temi robot allows for autonomous driving through mapping a space and creating preplanned routes, as well as for autonomously following people co-located with the robot. Other efforts have explored automatic height adjustment [26], automatic adjustment of interpersonal distance [53], tracking the face of a co-located speaker [34, 41], automatic gaze movement to avoid visual occlusions [39], attention guidance to movement happening outside the user's field of view [13] and even automated speech alteration to facilitate polite language [17]. Such implementations would require less input from the remote users and could alleviate some of the mental workload of operating the robot thus allowing them to better engage in various activities in the space they are visiting.

However, without disputing the potential advantages of the technology, we posit that the notion of independence through robotic telepresence merits closer scrutiny. Studies of MRP have pointed out that users face certain challenges that impede their freedom of movement. These include relying on stable internet connection throughout a space [18, 25, 38] and the absence of obstacles, such as steps, doors or narrow passages [28, 32, 32]. The movement of MRP devices also tends to be slower than human walking speed as well as more clumsy and inflexible [7, 49]. In addition, remote users of MRP have limited perceptual capabilities; their hearing and vision are not as clear, they can not discern the direction of different sounds and they can not sense their own volume or whether they are causing an obstruction to people behind them [7, 20, 29, 35, 49]. Moreover, whilst it may be obvious, it is worth emphasising that the remote user can only move in the space; they can not touch and manipulate objects in it. Consequently, as we discuss below, these limitations result in remote users of MRP often requiring regular assistance from their local peers —e.g., opening doors or helping them navigate narrow passages — as well as adjustments in the locals' behaviours — e.g., leaning in closer to speak and describing the environment [8, 9, 29]. In addition, some studies of MRP in education and older adult care note that the implementation of the technology requires a certain amount of training and infrastructural support [20, 30, 32, 38]. For example, a classroom needs to be made suitable for an MRP to move through it and a teacher needs to adjust lesson plans so that the telepresent student can effectively participate in the class and be suitably included in group activities. That is, regardless of how easily a remote user of MRP, assisted by automation features, can operate their device, the mediated space and people in it need to be appropriately prepared for the use of the device as well. Overlooking the complex social relationships between the primary user of an MRP device and the people who interact with them and support them in their use is bound to result in the technology being abandoned [21, 22]. Taking these considerations on board leads us to question whether complete independence through MRP is truly possible or what that form of independence means.

2 AN INTERDEPENDENCE FRAME FOR MOBILE ROBOTIC TELEPRESENCE

Assistive Technologies (AT) have long been seen as a medium for enabling disabled people to assert independence [52], for example, wayfinding applications for blind people or augmented or alternative communication devices for people with speech or language impairments. Although AT at large is greatly valuable for the people who use it, some of the solutions proposed, the underpinning assumptions, and the narratives behind them have been increasingly questioned inside and outside academia, often by disabled people [24]. One of these critiques that we believe is relevant to the case of MRP is the Interdependence Framework by Bennett et al. [4], which asks AT researchers to rethink independence as the ultimate and unquestioned goal of research and innovation for people with disabilities. Drawing from the concept of Interdependence, established in Disability Studies [51] and Disability Justice Activism [33], Bennett et al. outline the following four tenets: "*An interdependence frame (1) focuses on relations, (2) helps us make sense of multiple forms of assistance happening simultaneously, (3) draws out the often-underwritten contributions of people with disabilities, and (4) can help disassemble hierarchies that prefer ability.*" [4, p.164]

Interdependence in disability and accessibility thinking thus means discarding notions of full independence, as it is normalised for non-disabled individuals, and moving towards notions that recognise and embrace our dependencies with tools, with other people, and with the environments we inhabit, i.e. nobody is truly fully independent. We believe this is a lens that can be useful beyond the area of AT, as it stems for acknowledging the interdependence of *everybody*. As such we argue that it is worth applying it to areas outside of AT studies, such as robotics and AI, given that people with disabilities are commonly the anticipated beneficiaries of autonomous systems, —for instance, MRP being used to provide access to places for people with mobility impairments [54]—, but also looking the broader implications that automation would have on everyone's lives. To the best of our knowledge, Bennett et al.'s Interdependence Frame is not cited in HCI or HRI outside of work directly relating to disability, and yet a great deal of autonomous and robotic systems are aimed at making things easier or assisting users (of all abilities), and implicitly operate under an 'individualist' or independence-focused approach.

3 INTERDEPENDENCE IN ACTION: MRP EXAMPLES

In here, we apply the tenets from the Interdependence Frame [4] to analyse and scrutinise the case of MRP, using information from previous literature —including our own work—, which ranges across settings and contexts such as workplaces, homes, and public spaces.

However, to ground our argument, this section will focus on the example of using MRP in an organisational setting since a considerable amount of work on MRP explores applications in such spaces; offices, schools, hospitals [27]. These are in essence private settings managed by companies or institutions, but which nonetheless borrow some characteristics from public spaces as they are frequented by various types of people throughout the day. We will focus on the example of an office as a more general setting, aspects of which can then also apply to more specialised settings (such as the post-surgery hospital ward [19]), as well as to more overtly public spaces (such as a museum [2]).

We base this case study on a real office deployment that was reported by Boudouraki et al. (2023b), where a company brought MRP devices into their office space in order to make it more accessible to remote employees. We also consult numerous other studies showcasing what happens during use [e.g., 8, 40, 48, 50]. Below we explore the various relations that exist between the remote users and the various other stakeholders of that setting and the forms of assistance, work and hierarchies that are dynamically engendered as the technology is used.

3.1 Relations

Bennett et al. (2018) use the term relations to describe"a coming together of people and things in a particular moment in time". In the case of MRP used in the office, we have the remote employees as the main users (remote users) and the in-person office employees who may interact with the remote user or simply share the same space (local users).

However, the effective deployment of this technology in the organisational setting also involves several other members; staff in charge of the building's facilities who must maintain safety regulations, IT workers who manage the robot log in system and ensure that it is secure, various administrative staff who ensure that remote employees are integrated in meetings and company events and the employees who initiated and are managing the deployment [10]. These are people who do not come into contact with the robots as direct users, but who's work nonetheless involves supporting the use of the robots.

3.2 Simultaneous Assistance

The Inderdependence framework highlights that various forms of assistance can occur simultaneously.

Let us take the example of a remote employee who uses the MRP device to attend a prototyping workshop taking place at the office. As the technology allows them to move around the room, they closely observe what others are doing and are thus better able to assist. Through this independent movement they can take more initiative (rather than wait for others to come to them with questions) and they can provide more detailed and personalised advice to their peers.

However, as we noted earlier, the mobility of MRP devices and the capabilities they afford the remote user are generally limited in comparison to those of in-person, able-bodied individuals. As such, whilst assisting with work at the office, the remote user also receives regular assistance from their colleagues so that they can effectively access the space. This can include moving chairs out of the way so that the robot can pass by the table, describing things that the user is not be able to see well, holding doors open, pressing elevator buttons, letting the user know whether the robot's volume is too loud or loud enough and even perhaps picking up the device and manually moving it to another part of the office [7–9, 29, 35]. These types of actions will happen throughout the time the remote user spends at the office through the robot; help will be given and received in both directions.

3.3 Invisible Work

Next, Bennett et al. highlight that the provision of accessibility accommodations needs to be studied alongside all the sociotechnical elements that allow that provision to be used. Similarly, with MRP it is not simply a matter of providing the device; a lot of "work" is needed to make it work. As demonstrated by Boudouraki et al.(2023b), the deployment of MRP in an office might require Health and Safety experts to assess whether the ways in which the device functions pose any safety risks to employees and identify any obstacles to accessibility and inclusion. Then, IT specialists are needed to connect the devices to a secure network and set up a system that ensures that only authorised members (in this case company employees) gain access to the devices. Finally, staff overlooking the maintenance of the building must ensure that the position of the robots in the space does not block emergency exists or pose tripping hazards. Given than these are mobile devices, and given that people regularly join or leave the organisation (or enter the premises for brief visits), a lot of this work is continuous. The use MRP —or other mobile robotic devices— then is not simply a matter of purchasing this technology, turning it on and using it.

Moreover, there is a lot of hidden work performed by the users. The limitations of the robots in terms of speed and capabilities mean that users often have to plan their use in advance find ways to enlist the necessary assistance [9]. Our user might check that they know where the meeting room is in relation to the location to the robot docking stations, arrive early to make sure they have enough time to ravel there and message a friendly colleague to help them get through doors [9, 11]. During use, as well, there are various types of "work" that they will perform to help others interact with them. Studies suggest that remote users do things to make their perspective less weird and mysterious to local peers (e.g., describe their perspective, highlight that the robot is a separate entity or announce obstacles as they encounter them) [8, 12]. Through this process, users directly or indirectly communicate to others what the technology is doing, how much of it is intentional and what aspects of it are due to automation. This allows others to anticipate subsequent behaviours, and thus build trust with the system and its user based on a continuously updated understanding of what is going on during use.

This work is not obvious at face-value, it takes place before use or is intertwined with the interaction itself.

3.4 Revealing Hierarchies

The Interdependence framework, by identifying relationships of reliance, can reveal and challenge implicit hierarchies that exist between people. In telepresence we see that remote users regularly rely on assistance to do very mundane things (such as open a door). This continuous and unavoidable reliance may put them in a subordinate position to local others (similarly to how disabled people are traditionally viewed) [15]. Whether due to this reliance on help, or other reasons relating to their robotic appearance, studies find that remote users of MRP are indeed are often treated differently by locals. Examples range from small (and perhaps accidental) disrespectful behaviours (such as touching and muting the robot) [29], to being excluded from interactions [6, 44], to bullying [40].

At the same time, there is some evidence to suggest that pre-existing hierarchical relationships also affect the nature of interactions. Venolia et al. (2010) found that users' social standing within the organisation affected how much others valued the technology. Furthermore, asking for help or dealing with bullying and exclusion may be easier for people who have more experience in using the robot or who have a more secure position within the organisation [9]. If our imagined employee is a manager or director, their presence at the workshop will be highly valued, counteracting any negative aspects from the inconvenience of having to accommodate the robot in that space.

4 MOVING GOALS FROM INDEPENDENCE TO INTERDEPENDENCE

In this paper, we have presented a critical examination of MRP; a specific type of (semi) autonomous robot. Through employing an Interdependence Frame to analyse past work on MRP, we have highlighted relations, simultaneous forms of assistance, the under-recognised work required to use the technology, and the hierarchies between remote and local users.

Notably, the kinds of interdependencies we have identified are an inherent part of how this technology is used. Whilst improvements in the robots' technical capabilities, and an expansion of their affordances, might eliminate *some* forms of assistance, this will not remove the need for staff to ensure the safe and appropriate implementation of the technology. In addition, regardless of how well the technology functions, the remote users and all other individuals who come into contact with the technology will need to perform some "work" to establish appropriate ways of using the technology around one another [29].

Thus, we argue that research and design on MRP, and other autonomous or semi-autonomous robots, could greatly benefit from questioning their underlying motivations of independence. If we acknowledge that no individual operates in complete autonomy, it follows that robots are also limited in their independence and capabilities, regardless of claims or goals of full autonomy. This understanding is critical to setting realistic expectations for the role of robotics in society (i.e. at our homes, workplaces, and public spaces). In the same way that ensuring accessibility for people with disabilities is not a binary state but an ongoing accomplishment [5], access for and deployment of robots will require attending to our interdependencies; that is, recognising and accounting for existing hierarchical relations, simultaneous assistance, and hidden work [37]. Moreover, this interactional "work" between individuals, with and through the technology that supports them, is a vital element of process of building trust, as it enables us to build, update and monitor our understanding of what other agents (users or autonomous devices) are doing. As such future work might benefit from considering the multiple relations, access work needs and asymmetrical hierarchies that any given technology engenders and designing to better balance and support (rather than eliminate) those interdependencies.

Furthermore, in the same way that AT research and design has had to learn from disability theory and activism [23, 31], future work on robotics research and design ought to critically engage with disability thinking and disabled lived experience, particularly when the end-users of the systems are people with disabilities.

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