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First Steps of Designing Adaptable User Interfaces to Mediate Human-Robot Interaction

Fadma Amiche¹ and Marie Juillot¹ and Adrien Vigné¹ and Anke M. Brock² and Aurélie Clodic¹

Abstract—There is a wide diversity of platforms for teleoperating robots. Every robot, use case, and type of user brings a unique set of expectations. We propose that human-robot interaction should consider the opportunity to use an external device (such as a smartphone) to not only teleoperate but also mediate the interaction with a robot, either in telepresence or in co-presence. In this paper, we present first steps and ideas towards the development of this media. It involves, as first end-users, the members of the robotics department of our laboratory and considers all robotic platforms which are hosted there (assistance robots, terrestrial robots, robots humanoids, quadrupeds, etc.). We describe our user-centred design methodology, detailing the needs analysis and brainstorming sessions conducted. Following this, we outline the design and prototyping phases, showcasing the iterative development of our interface. Finally, we discuss the results from our evaluations and the implications for future work in creating flexible and inclusive interfaces for diverse user groups.

I. INTRODUCTION

There is a wide diversity of platforms for teleoperating robots, that are each declined in multiple versions. This diversity is partly due to the numerous types of robots. For instance, the user must teleoperate an outdoor robot or a drone remotely, while in other cases, the robot and the user are in the same room. In the case of remote control, the control interface must provide the user with a video feed of the environment and a map with its localization to ensure the robot's safe control, whereas if the user and the robot are in the same room, the map or camera feedback might not be needed. In the case of a social telepresence robot [1], the perception of co-presence needs to be considered.

The diversity of devices and platforms is also due to the different types of users and use cases. For example, a professional remote drone operator needs to have everything on the interface to pilot the robot normally and in difficult situations. A roboticist needs error logs to manage them and debug them. On the other hand, a layman (e.g., a child) should not have to manage error cases (and thus, for instance, requires automatic reconnection in case of loss).

Every robot, use case, and type of user brings a unique set of expectations.

We propose that human-robot interaction should consider the opportunity to use an external device (such as a smartphone) to not only teleoperate but also mediate the

interaction with a robot, either in telepresence or in co-presence. With smartphones and tablets we already possess very powerful devices with performant hardware:

Good microphone and speakers: While fluid interaction between humans and robots through speech and gesture is not yet possible [2], [3], speech recognition is today impressive on mainstream devices. Moreover, the feedback of the robot through this device would also prevent issues (e.g. regarding the presence of noise) and allow easy adaptation on the user side (e.g. use of headphones or personal settings)

Good cameras: Good quality image recognition would enable gestural recognition. Moreover, it could be possible for the user to take a picture of an object or a person to provide information about that object/person to the robot (or ask questions about the content of the image).

High quality display with (infinite) possibilities in graphical interface design: The video stream and other information perceived by the robot can easily be displayed, as well as a graphical user interface that enables interaction between the user and the robot.

Display with touch recognition: Touch interaction is natural for today's users. An interface using buttons and other standard widgets is an obvious choice. But also richer interaction can be imagined. For instance, from the recognition result of the robot displayed on the device, we can imagine that the user simply clicks on a detected object to ask the robot to pick it up.

Access to user data, preferences and profiles: The interface could easily adapt the interaction to user preferences, in the case of elderly people, children, or people with special needs.

Last, but not least, the way to use such a device is common knowledge for a large amount of the population. In front of the growing variety of robot design, it could help to tackle the heterogeneity in existing interfaces to enable human-robot interaction. Moreover, besides the possibility to mediate the interaction, this device could help to frame it (e.g. we can imagine displaying on the device the robot's abilities and limits, how it could be used, even to have a tutorial). Consequently, we think that the use of this media as an interface could help to tackle the problem of mutual recognition, while "Recognition is key to successful cooperation with robots because once mutual recognition has been established between agents: (1) the others become resources for me in a way that promotes equality and sharing, which in turn enables (2) more and other information to be shared and exchanged in Human Robot Interaction." [4].

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Our approach is to design a modular interface that adapts to these diverse factors, applying user-centred design methods. We are committed to creating an interface and a media compatible with a wide variety of robots, which can adjust to each robot’s specific requirements and can be personalized by the user.

In this paper, we present first steps and ideas towards the development of this media. It involves, as first end-users, the members of the robotics department of our laboratory and considers all robotic platforms which are hosted there (assistance robots, terrestrial robots, robots humanoids, quadrupeds, etc.). We describe our user-centred design methodology, detailing the needs analysis and brainstorming sessions we conducted. Following this, we outline the design and prototyping phases, showcasing the iterative development of our interface. Finally, we discuss the results from our evaluations and the implications for future work in creating flexible and inclusive interfaces for diverse user groups.

II. NEEDS ANALYSIS METHOD

A. User-centered design and participatory design method

We opted to apply user-centered design and participatory design methods, which involve target users throughout the design cycle ([5], [6]) to ensure their needs are taken into consideration. Indeed prior work in robotics argued that humans should be at the heart of work in robotics [7]. This process is generally iterative and divided into four stages: 1) Needs analysis (e.g., through interviews and observations); 2) Design (e.g., through ideation sessions); 3) Prototyping (low and high-fidelity mockups, e.g., on paper, video, or computer); 4) Experimental evaluation (quantitative and qualitative measures).

As part of the needs analysis and design stages, we organized two brainstorming sessions. The first brainstorming session included permanent members of the robotics department of LAAS-CNRS¹ and the second included PhD students and interns. Participants were divided into two groups to achieve an ideal number of participants per session. The division was made between permanent and non-permanent members following a request from a PhD student who felt uncomfortable expressing ideas in front of permanent staff.

B. Needs analysis through brainstormings

Brainstorming 1: Permanent Members. This session included nine permanent members and one post-doctoral researcher, comprising two specialists in outdoor robots, two in drones, two in assistive robots, one working on robotic arms, one specialist in humanoid and quadruped robots, and two members from the robotics platform experienced with all types of robots.

Brainstorming 2: PhD Students. This session included eight PhD students, four of whom worked on assistive robots, two on terrestrial and logistics robots, one on transmedia robots, and one on imaging robots.

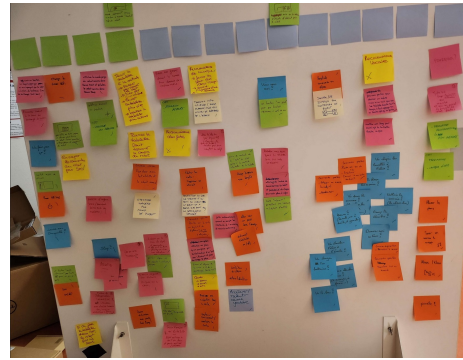


Fig. 1. Board filled with brainstorm post-it notes

At the start of each session, participants were briefed on the objective: to generate ideas for a teleoperation interface for robots. They were assured that all ideas, no matter how ‘wild’, would be treated with respect. Participants were encouraged to think beyond current capabilities and propose systems, interaction modes, or actions. Participants were asked to suggest at least three ideas, writing each one on a separate post-it note. The instructions were: “For the robots you use and the use cases you are familiar with, you are invited to design an interface on a tablet (with a joystick optionally). What would your ideal interface look like? Consider aspects such as information display and placement, possible commands, and how to manipulate them (interaction ideas)”.

After the initial idea generation phase, participants spent about fifteen minutes writing their ideas on post-it notes. This was followed by a collaborative thirty-minute session where all ideas were presented and grouped into categories as presented in figure 1. Finally, a vote was conducted to select the most interesting post-it notes in each category, emphasizing the collective decision-making process.

C. Results

Brainstorming 1: Permanent members

During this brainstorming session, the permanent members of the laboratory initially focused on the information to be displayed, followed by possible commands and how to manipulate them. This resulted in two boards containing forty-nine and eighty-eight post-it notes, respectively. These post-it notes can be classified into six distinct categories:

- **Vision and Detection:** Image acquisition by the robot’s camera to observe the room; Identification of people, obstacles, and surrounding elements; Correlation with the robot’s knowledge base.
- **State of robot actions (past/present/future):** Explanation of the robot’s intentions; Visualization of the robot’s future trajectory; Visualization of the robot’s expectations in interactions with humans.
- **Mapping:** Use of a 3D map for navigation; Defining goals to achieve via a map; Precise localization of the robot on the map.
- **Contextual Information:** Integration of weather data, date, and time.

¹<https://www.laas.fr/en/departments/rob/>

- **System Status:** Monitoring the robot’s battery; Managing potential errors; Locating charging stations.
- **Communication:** Measuring sound levels; Acquiring information about ambient noise in decibels.

Brainstorming 2: PhD Students

The PhD students addressed information, commands, and their manipulation simultaneously. This session produced one hundred thirty-eight post-it notes categorized into fifteen groups, nine of which were identical to those from the brainstorming session with permanent members. The new groups were:

- **User Information:** Monitoring physiological indicators such as brain activity and heart rate; Issuing notifications to encourage breaks if necessary.
- **Robot Usage:** Tracking data related to the robot’s usage, such as the last cleaning performed and the last person to use it.
- **Trust:** Assessing the robot’s trust in the user; Evaluating the robot’s confidence in its ability to perform specific tasks.
- **Motivation:** Integrating a gauge reflecting the quality of commands; Monitoring the robot’s mood; Recording the time the robot spends outside.
- **User Interface:** Implementing tools for the interface, such as drop-down menus and the ability to open multiple windows simultaneously.
- **Documentation** Accessibility of the documentation associated with the robot.

D. Discussion

The comparison of the two brainstorming sessions revealed a convergence in specific categories, suggesting their importance within the team. They allowed us to better understand our users and their needs, as well as the success criteria, which are: Being able to have video feedback of what the robot sees; Having a map with the position of the robot; Being able to control the robot by a distance; Having access to the system status of the robot.

III. DESIGN AND PROTOTYPING

Based on the previous results, we addressed the phases of design and prototyping.

A. Related work

a) Adaptability: Literature reviews differentiate between adaptable and adaptive interfaces [8], [9], [10]. An adaptable system is defined as a system that uses tools to facilitate modification of its characteristics by the end-user, while an adaptive system manages the entire adaptation process based on the user or the interaction tools (e.g., adapting to the display window size, context-aware display). According to prior work [11], adaptability is characterized by flexibility and consideration of UX (User Experience). UX is defined as a person’s perceptions and responses that result from the use and/or anticipated use of a product, system or service [12]. Within adaptable interfaces, we distinguish between “customizable” (the ability of an interface to be

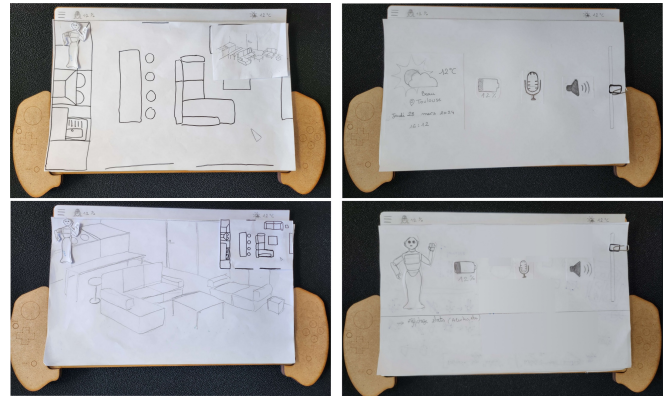


Fig. 2. Examples of paper prototypes

graphically modified by a user without changing its functionality, e.g., changing background colors, font size, font type) [10], “modifiable” (the ability of an interface to allow rearrangement of its components on the screen) [13], and “flexible” (allowing different interfaces to be presented based on the user’s profile) [14].

b) Accessibility: Robotics engineers are not astronauts, so some might have less-than-perfect vision, either due to age, close- or far-sightedness, or colourblindness. Some may need glasses for their impaired visions. Some might have tremors or problems pointing at small and precise locations. These issues have to be accounted for while creating the graphical user interface, for it needs to be used comfortably by diverse users.

B. Method

a) Participants: Twelve people participated in the experiment: three doctoral students; an intern, and a postdoctoral researcher in HRI working with social robots; two research engineers managing the entire robotic platform of the lab; a doctoral student working with drones; and four doctoral students from non-robotics fields for comparison with naive users. One person was color-blind.

b) Iterative method: Our design process was iterative and user-centric. Initially, we created disposable paper prototypes (Fig. 2) to generate a wide range of ideas quickly and encourage user feedback without hesitation. Since paper prototypes are quick to produce, users feel more comfortable criticizing them during testing sessions [15]. After each round of user testing, we gathered feedback and used it to refine the prototypes. Once the design was refined through these iterations, we transitioned to creating Figma prototypes (Fig.5). This stage allowed us to develop a preliminary design version and integrate essential UX elements. Once the Figma prototypes were validated, we proceeded to the coding phase.

C. Design of an accessible interface

In order to design an accessible interface, we paid attention to the sizes of the buttons and the interactive elements. Indeed, these items need to be clickable by all users, including those who are less used to tactile equipment, visually impaired, or have tremors.

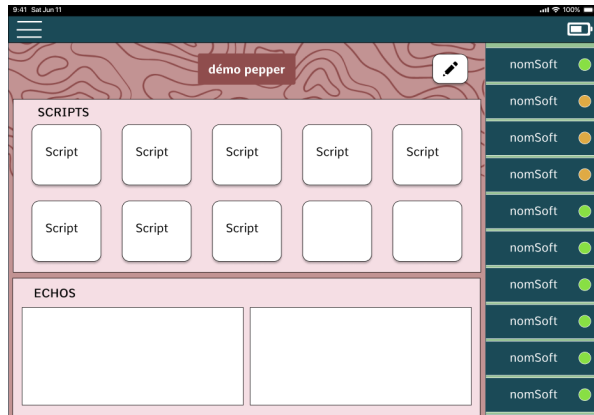


Fig. 3. Example of display

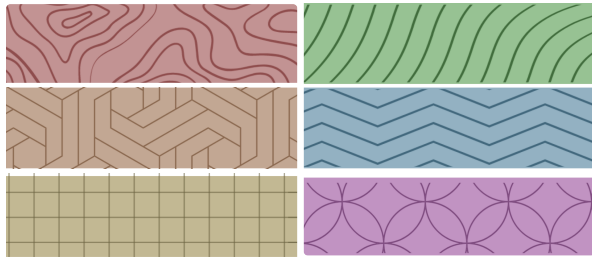


Fig. 4. Example of patterns for enhancing lisibility for color blind users

A color palette was picked in accordance with color theory [16], with a focus on blueish-green hues. The contrasts between the background color and the fonts were checked in order to make sure that text would be legible. An example is shown in Fig. 3.

The prototype required several pages that were variants of each other. We wanted them to be distinguishable almost immediately. A second color palette was then picked, comprised of matching muted hues of six of the rainbow colors. A page was attributed a single color theme, making them visually different (Fig. 4).

However, we needed to account for colorblind users, who would not be able to differentiate the pages by the colors. Therefore, patterns were added to the six colors. A single pattern was tied to a single color, as depicted in Fig. 4, so we could recreate that same instant recognition. These specific patterns were picked because they were strikingly different, but not too over-elaborated as to overwhelm the user. Adding another item on the page meant adding another darker hue for each color. The contrast between the background hue and the pattern hue was tested, to make sure that the pattern would stand out even to someone with colorblindness.

IV. EVALUATION

A. Prototypes

The user tests that were run during the prototyping phase consisted of interviews, with a focus on qualitative feedback. A total of twelve participants were solicited over the course of two rounds of interviews, some multiple times. They were asked to handle the low-fidelity paper prototypes like they

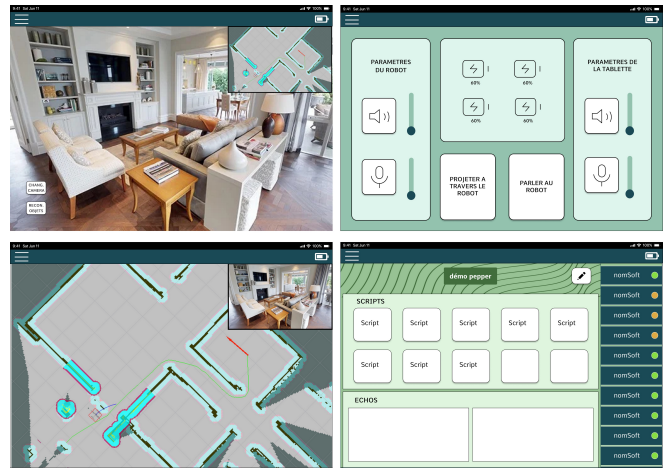


Fig. 5. Final Figma prototype of the interface (top left image: robot's camera feed, bottom left image: robot visualization on the map, top right image: status page, bottom right image: script launch page for the robot)

would the final one, to explore it freely, and to think aloud about their actions and what consequences they would have on the interface. They were then asked to accomplish four tasks: move the robot from a point A to a point B, make the robot grasp an object, raise the sound of the tablet through the interface, and lower the sound of the robot. Afterwards, they were allowed to ask more questions and give feedback on what they wanted to add or remove. Notes were taken on their thought process and feedback, that were compiled into a chart and used for the creation of the subsequent prototypes.

We wanted to see how the participants imagined accomplishing the tasks, in order to design the interface based on the users' expectations. Once we had the design idea, running the same protocol allowed us to verify that it was correct. Some of the major takeaways from these interviews were that two specific pages depicting settings (one for the tablet, one for the robot) were too similar and confusing. For the subsequent prototypes, we fused these two elements in order to make their use easier. Several questions were raised, for example, on the relevance of having a virtual keyboard on such a small device, or on the mapping of the controller's buttons. Some participants made the request of being able to click on objects in the robot's view to learn more about them. Once the interviews were done with the paper prototypes, we conducted similar interviews with the Figma version.

B. User Experience

Once the final prototype was conceived, but before the colors were added, we tested it with the User Experience Questionnaire (UEQ) [17]. Its six scales are Attractiveness, Perspicuity, Efficiency, Dependability, Stimulation and Novelty. It measures aspects of pragmatic quality (efficiency, perspicuity, dependability), and aspects of hedonic quality (originality, stimulation). This questionnaire was chosen rather than any other because it did not put too much emphasis on the interface's aesthetic aspect (e.g., color choice) but rather on the features' perceived usefulness and the efficiency of the page composition.

Four participants, future users of the final interface, were picked to fill this questionnaire. They were asked to do the same tasks than during the previous tests, then answered the UEQ. Besides, they had to answer 3 requests: "List the 3 aspects you like the most.", "List the 3 aspects you like the least.", and "Do you have any suggestions to improve the interface?". The data obtained was analysed through the tool provided on the UEQ website². The results, compared to the benchmark for the six scales, showed that the interface was perceived excellent in Attractiveness (mean=1.88, SD=0.37), Efficiency (mean=1.94, SD=0.47), Dependability (mean=1.94, SD=0.47), and Stimulation (mean=1.81, SD=0.43), above average in Perspicuity (mean=1.44, SD=0.66), and approximately average in Novelty (mean=0.38, SD=1.05). We theorize that the low score obtained in Novelty, and overall look, might be due to the early stage of design, the interface tested being in black and white with basic shapes and fonts. Additional tests conducted with more users, and once the interface is implemented, will allow for verification of this hypothesis.

C. Design

For the colors, the varied contrasts between background, font, and other several elements were checked using the site whocanuse³. This tool takes into account multiple visual deficiencies such as all variants of colorblindness, glaucoma, cataracts, but also situational events like the impact of direct sunlight and the "dark mode" shift of the user's system. The contrast ratios of the pairs between the lighter background colors and the darker pattern color for the six variants ranged from 5.99:1 to 6.76:1, confirming that the patterns would stand out for every user. As far as the several texts elements and their background, the contrast ratios of the fonts (either black or white) ranged from 5.99:1 to 18.39:1. On top of using this tool, a colorblind user was able to confirm on an informal level that the patterns were strikingly different, as well as useful and immediately recognisable.

V. CONCLUSIONS

In this study, we have explored the potential of leveraging external devices, such as smartphones and tablets, to enhance human-robot interaction through teleoperation and mediation. Our approach emphasizes integrating these devices as versatile interfaces that adapt to diverse user needs and robot functionalities. We chose to employ the user-centred design methodology, which involved comprehensive needs analysis and iterative prototyping, informed by end-user feedback within our robotics department. This inclusive process highlighted essential interface elements—such as video feedback, mapping, and system status—and underscored the need for flexibility and accessibility in interface design. The diverse requirements gathered during brainstorming sessions reflect the complexity and variety of interactions that users wish from robotic systems. The iterative design and evaluation phases revealed valuable insights into interface usability,

particularly regarding adaptability and accessibility. Our prototypes, tested through both low-fidelity paper models and high-fidelity digital versions, demonstrated the efficacy of designing with user feedback at the core. While this work represents only an initial step, it demonstrates a keen interest in interacting and communicating with a robot via an external device. Future developments will be necessary. However, the current setup is highly customizable and adaptable, making it feasible to deploy this platform soon across multiple robots in our lab. Additionally, we plan to implement this on a telepresence robot for hospitalized children.

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²<https://www.ueq-online.org/>

³<https://www.whocanuse.com/>