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LHF Connect: A DIY Telepresence Robot Against COVID-19

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ABSTRACT

This contribution describes a case study of a “do-it-yourself” (DIY) opensource service and related product to help combating the COVID-19 emergency. It illustrates the birth of LHF Connect, a project designed to facilitate communication between patients isolated in COVID-19 hospitals’ ward and their relatives. LHF Connect is a teleoperated robot that can move in autonomy around the hospital. A User Centered Design approach, methods and specific tools helped in managing crucial steps of the design process such as i) the collection of needs coming from the context, stakeholders and end-users; ii) defining the service blueprint; iii) imagining finishing concepts; and iv) managing the communication activities. The initiative has been promoted by a multidisciplinary team of researchers (mainly roboticists with the help of specific competences coming from Design discipline).

Keywords: Communication, COVID-19, DIY, Opensource, Robotics, Telepresence.

INTRODUCTION

Since the beginning of March 2020, Italy has been the first European country strongly affected by the COVID-19 outbreak. As a consequence of this, the government put in place restrictive measures for the population to contain the spread of the virus: the so-called lockdown. In a short time, the whole world had to look for effective measures to limit the damage caused by the pandemic. To date (July 1, 2020) more than 10 million infections and 500,000 deaths have been reported worldwide due to the virus. Almost all states affected by COVID-19 have imposed the so-called "social distancing", the restriction of access to public places, offices and schools, and a travel ban. This led all citizens to change abruptly their personal and family life, as well as their working habits, thanks to tools that allowed working and communicating despite physical separation. If at first, some people's reaction was to postpone appointments and meetings for a couple of weeks, as time went by (and weeks became months), it appeared clear that long times would have passed before returning to the pre-COVID normality: a new normality started to take shape.

1. THE DEMATERIALIZATION OF CLOSENESS: THE WAY TO REMOTENESS IS NOT OBVIOUS AT ALL

All the encounters and meetings that previously took place in presence have been dematerialised and became once again possible thanks to technology. A pivotal role in this transformation was played by audio-video communication tools able to manage many remote users, examples include Microsoft Teams, Zoom, Google Meet, Skype, Cisco Webex, Bluejeans, Houseparty, etc. This transformation has been true for companies, switching in remote meetings between colleagues, clients, and suppliers, but also for events, fairs, conferences and training activities. Moreover, also personal encounters changed, for example in the way one heard from their relatives and friends during the lockdown phase. Most in-presence encounters have been transformed virtual and remote, dematerialised and digitized.

Observing this transition, two observations can be made. First, all communications became technology-dependent and mediated, which means that the richness - quantity and quality - of the information transmitted depends on the used technology. If, on the one hand, tools that manage well the audio and video data of many users are available, currently we do not have technologies that can faithfully convey the experience of a meeting in presence, which is composed of many physical elements, such as non-verbal communication, body language and proxemics, and is strongly influenced by the context (environmental and cultural).

A second observation concerns the timing and methods available to express and discuss among participants. The digital tool stiffens the modality of communication between people, caging the possibility of expression into predetermined time slots. This way of being together and communicating limits the naturalness and multiformity of the discussion between people who – in presence – dispose of different informal moments to confront each other. Consider, for example, that informal discussion, networking and brainstorming often take place also during coffee breaks and taxi rides. Currently, technology seems to fail in reproducing the completeness and complexity of human nature.

In general, during the early phases of the pandemic, there was controversy about what technology could and should do to help in solving the emergency. In particular about Robotics, on April 9th 2020, Riccardo Luna wrote provocatively on La Repubblica: “Ma che fine hanno fatto i robot?” (What happened to the Robots?) (Luna, 2020). Major scientific journals have been following the debate, inspired by what happened in the past and by fiction (Murphy, 2020). In their editorial on Science Robotics, “Combating COVID-19-The role of robotics in managing public health and infectious diseases” published on 25 Mar 2020, Yang et al. asked: “Could robots be effective resources in combating COVID-19?”

1.1. A Case Study

The case study that we report, comes from the field of research in robotics for rehabilitation and human cooperation and shows the contribution that the Design discipline has provided to this experience, by helping in managing some crucial aspects. In particular, the case study illustrates LHF Connect, a small avatar robot (teleoperated remotely by volunteers) designed to connect people isolated due to the COVID-19 with their relatives and friends: the first working prototype of LHF Connect and service blueprint was developed in about 3 weeks (on April 9th it was tested in hospital).

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The support of the Design discipline has been crucial for some specific aspects such as: i) collecting and reading the needs in order to design a technological concept able to help in combating the COVID-19 emergency in a short time; ii) managing the service blueprint of the solution proposed, iii) diffuse the project to make it available to the largest audience possible in a short time and to local institutions and hospitals. Finally, iv) some concepts for the finishing of the robot have been produced.

2. A USER CENTERED DESIGN APPROACH

Since its beginning, the LHF Connect project adopted a User-Centered Design approach (UCD), considering users and their needs, together with the stakeholders' requirements, at the centre of the entire design process. We pursued this goal following a holistic approach that considered both the physical and cognitive characteristics of individual users (in most cases patients in COVID-19 wards of hospitals), as well as the social and organizational aspects of hospitals during the pandemic emergency. The process has been inspired by Norman & Draper (1986): end users have been involved as well as stakeholders identified, such as doctors, nurses and all personnel that works in the institutions (hospitals and nursing home) that accommodate COVID-19 patients, as cleaners, administrative staff and managers.

A first prototype has been delivered in two hospitals of Tuscany in early April 2020, then tested and refined following users' and stakeholders' indications until June 2020. The UCD process was characterized by a spiralling recursive design process that started from inquiries about the needs during the emergency and followed with context specifications, service design and usability testing.

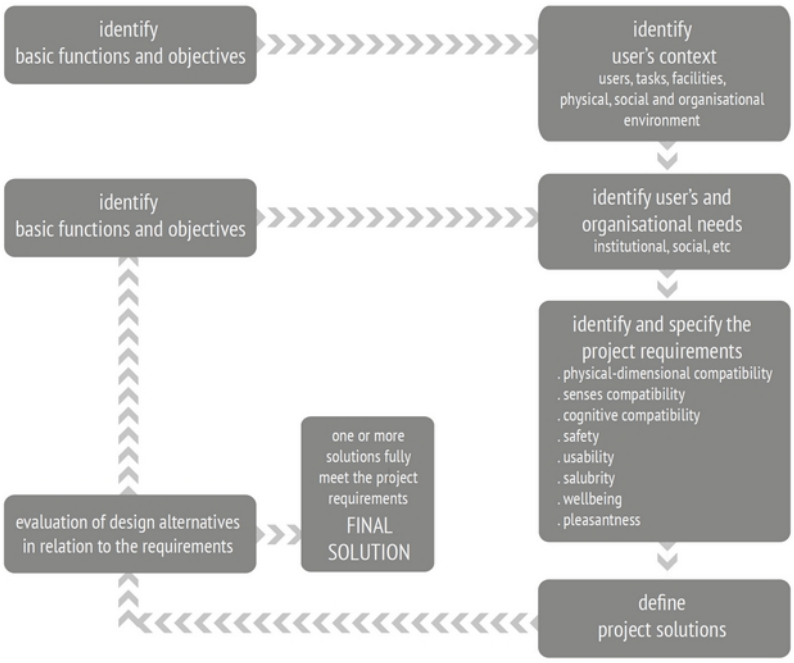

Figure 1. The UCD approach applied to the LHF Connect design process (Fubini, 2009).

The Design discipline had the opportunity to actively contribute to the development of LHF Connect. If for scientists in robotics, the goal - above all - for basic and medium-term research is represented by the technology itself, through the LHF Connect project the short time to develop the application conquered the centrality of the entire design process. Focusing on the application of a technology means dealing with end-users and the stakeholders, defining a service with strong time constraints and context specifications.

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It was thus possible to apply the approach that sees the "designer as an apprentice" (Beyer and Holtzblatt, 1998). Contextual inquiry was promoted to foster this idea revealing some important issues:

> "Seeing the activities reveal what matters. Nobody can talk better about what they do and why they do it than they can while in the middle of doing it. Seeing the work reveal details. Talking about work while doing it protects the master craftsman from the human propensity to talk in generalisations. Seeing the work reveals structure. A master craftsman teaches his apprentice how to do the work. This is what he is expert at. But a designer must understand structure and implications: the strategy." (Beyer and Holtzblatt, 1998)

Moreover, the SAY-DO-MAKE model from Sanders and Dandavate (1999) provided the methodology to be applied during the users' observations and inquiry to tailor specific solutions – mainly related to the service design – oriented to context needs, to the robot usability and the final users' experience. The authors wrote that for an appropriate understanding of user experience there is the need for a set of different data sources: Verbal data ("say", what people know and say); Data on behaviours ("do", watch and observe what they do); Data on emotions and dreams ("make", the use of non-verbal means to describe and represent the experiences).

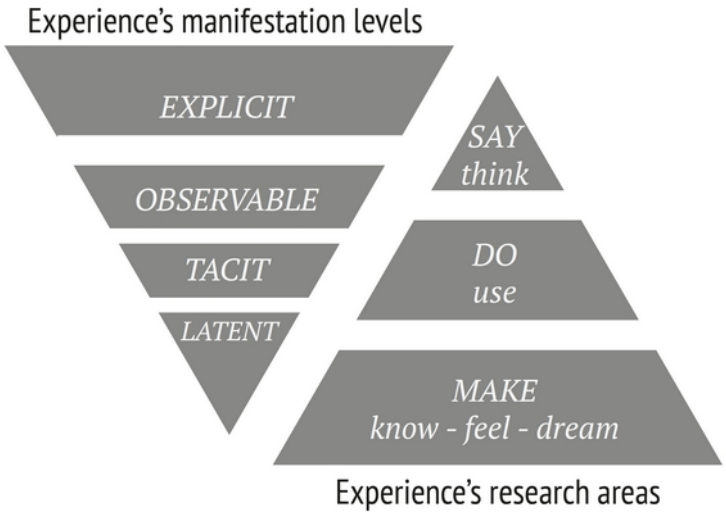

Figure 2. The SAY-DO-MAKE model from Sanders and Dandavate (1999).

2.1. A coalition of researchers against COVID-19

During the lockdown, many initiatives were raised to help in combating the pandemic. As said, technology had a central role and in Italy, the Makers Movement had a primary role in imagining solutions that could be available in **a short time** (Bassi, 2020). Time and availability constraints had a central role in combating the pandemic with tangible solutions. A collection of **short-time projects** proposed during the emergency has been made available on the Tech for Care platform (https://techforcare.com/en/solutions/). This platform constitutes a sort of coalition to bring together the ability of communities of technology experts to respond to the pressing needs of all emergency workers. The website presents three areas: Needs (intended as the needs collected from emergency workers); Solutions (technologies and projects); Implementations (FabLabs and companies that could implement and produce solutions). Projects are accessible and available to everyone.

In parallel, also those products with a high level of technological readiness and potentially available for general use in the **medium term** constitute a reference to define a sort of state of the art of the technological solutions that could be useful to fight the emergencies deriving

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from the global spread of COVID-19. Italian Institute of Robotics and Intelligent Machines (I-RIM), a non-profit organization of national stakeholders that promotes robotics to improve citizens' quality of life and well-being, has analysed different solutions on an online collection of Pilot Projects: 70 examples of technological demonstrators, tested in the clinical field, that can be developed into products useful in combating the virus.

Within this context, **LHF Connect project was designed to be a short-term solution** and finds among its main sources of inspiration two specific studies conducted by I-RIM that collected and interpreted needs arising during the pandemic. I-RIM launched **two questionnaires** to collect needs during the different phases of the pandemic to gather information on the citizens' needs, to investigate problems that people face to work safely and efficiently, and to understand the impact such a dramatic time had on their psychology (Sciutti et al. 2020).

I-RIM developed the first questionnaire to understand the needs related to the lockdown phase, with the scope to limit the possibility of contagion during professional activities, while a second one has been launched after the lockdown, in early July 2020, to investigate the objectives necessities but also psychological needs of the recovery phase.

About 200 people answered the first questionnaire describing how the pandemic influenced their life and work. Respondents were mostly working in healthcare (about 30%), research (about 19%) and education (about 9%). Activities were found to have moved to agile working at a rate of about 50% of respondents, forcing many to abruptly switch to a novel, virtual work dimension, characterized by the impossibility of natural interaction with colleagues, patients, and students (Sciutti et al. 2020). Many participants mentioned the possibility of teleoperation in different fields (with the use of drones and autonomous machines) to diminish infections.

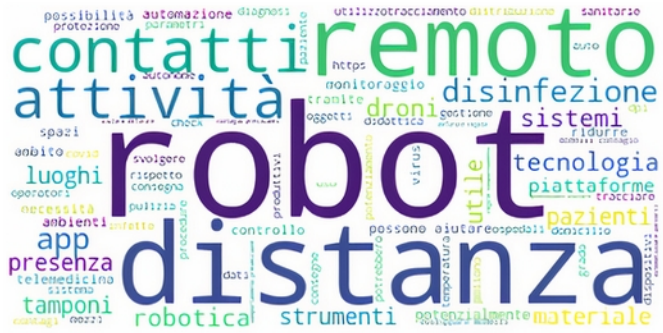

Figure 3. This word cloud that resume answers at the following question: "Do you have any suggestions on how technology can help?"

3. THE BIRTH OF LHF CONNECT PROJECT

3.1. COVID-19 Hospital Needs: Identification and Definition Of Tasks

Since the COVID-19 spread in Italy, the team of researchers focused on some **unstructured in-depth interviews** (Rizzo, 2009) **with sanitary staff and primaries** from different hospitals and co-designing with them possible solutions. Since the beginning, one necessity emerged clearly: patients were isolated in COVID-19 hospital wards, without any possibilities of being visited by relatives. Many of them were elders, whom the digital divide (Romano et al. 2015) often prevents the possibility of using audio-video communication tools. The result was the complete isolation of these patients and leaves as sole information

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to their relatives the medical bulletin provided through a short phone call made by nurses. Many patients passed away without having the possibility of saying goodbye to their loved ones. Moreover, COVID-19 hospitals suddenly faced an increase in patients, the sudden need to treat them without compromising the health of the hospital personnel: clinicians, nurses, technicians, and cleaners. This made the personal protective equipment used to safely get in contact with patients and the surrounding environment become pivotal, together with the need for a continuous re-supply (Griffin et al. 2020, Ranney et al. 2020).

On the other side, hospitalized patients were kept isolated from the outer world and their only relations were with "draped" clinical personnel, often barely recognizable. Nevertheless, patients needed support, comfort, proximity, and reassurance (Negro et al. 2020). This fact, together with the fear and anxiety shared with many other serious illnesses, compromised the psychological status of the patients, who coped less favorably with acute and post-acute symptoms. In this context, one of the needs for caregivers was to provide some psychological relief that may reduce the burden of comorbid mental health conditions and ensure the wellbeing of those affected.

Hospitals recognized the need to help patients to get in touch with their family, helping the elders with tablet and smartphones to arrange video calls (Wakam et al. 2020). Dedicated services and infrastructures rose all over the world (Ohannessian, Duong et al. 2020). At the Humanitas Mater Domini in Castellanza (Varese) nurses used a tablet for this scope (Rainews, 2020). The same happened at Policlinico di Bari (Il Quotidiano, 2020) and Ospedale Martini in Torino (Torino Oggi, 2020). In Bergamo, Croce Rossa Italiana started a service to provide video calls in COVID-19 wards. Voluntaries entered the COVID-19 ward to provide patients with video call on a tablet (CRI, 2020). If on one hand these initiatives go in the same direction as LHF Connect , by providing a sort of video call service, on the other hand, some disadvantages emerge from these initiatives: i) often nurses are strongly involved in providing the video call service while the opportunity/challenge was to free them, already overloaded of many patients; ii) otherwise, volunteers in presence are needed, with a significant expense of time and disposable personal protective equipment, which is necessary to enter in the COVID-19 ward; iii) volunteers are exposed to the possibility of contagion; iv) tablets or smartphones have to be touched with the possibility to convey the contagion.

3.2. Project Brief: Low Hanging Fruits From The Research Know-how

Thanks to the team's strong experience in research for **telepresence** with humanoids robots (for a definition: https://en.wikipedia.org/wiki/Telepresence) ideas came up quickly: their know-how could be adapted in helping to overcome this lack of communication. The concept, generated around the end of March 2020, was to realize a remote-controlled robot (teleoperated by remote volunteers) that could move around in the hospital ward, carrying a device for video-communication directly to the patients' bed. A simple robot, named LHF Connect, that could be easily replicated in different hospitals during the lockdown, without requiring specific competences. The name LHF indicates the acronym Low Hanging Fruits, i.e. those fruits of the tree of most advanced robotic research, which maturated in the recent years and are now at hand, for a vast and immediate application.

LHF Connect project - using robotics and in particular telepresence - provides some *advantages* when compared to other similar initiatives: i) the service could be managed

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remotely, offering the possibility to free medical personnel, already overloaded by the many patients; ii) no volunteers are needed in presence, with significant savings in terms of time and disposable personal protective equipment; iii) the telepresence robot remains in the COVID-19 ward, without any possibility of being a possible vector of the contagion; iv) all operations are managed remotely so that it is never necessary to touch any device onboard the robot.

3.3. Time and Availability Constraints

The technology to provide robots for telepresence with a mobile base is already there: the issue was not to hit any technological barrier, as demonstrated by **products already on the market** such as Beam Pro, InTouch Vita, Ubbo Expert, Zora or Pepper (for more information visit: www.irim.it/en/pilot-projects/). Unfortunately, they were simply not enough to face the emergency, very expensive and usually designed for other purposes. Moreover, most of the products mentioned could not be produced in a short time. Other projects **such as** AlterEgo (https://www.youtube.com/playlist?list=PLzEoYml21jz5Xraq_-x07uf0TgLIXxVc7) were already meant and tested for assistive teleoperated purposes but, unfortunately, are still **research prototypes**.

3.4. The Concept

The teleoperated robot was assembled using off-the-shelf hardware, easily available even during the lockdown (e-commerce never stopped delivering in Italy), to be assembled and used by non-specialized personnel. The service is managed remotely by the external coordinator (a volunteer). A voluntary teleoperator drives the robot to the patient's bedside and calls the relatives from the mobile device onboard LHF Connect. It uses standard communication software (WhatsApp), for three-way communications. The teleoperator starts the communication, then leaves the meeting, and returns when the allotted time is finished, to gently stop the conversation and take the robot elsewhere. All personal information is managed by the external coordinator, who guarantees correct privacy management (according to the General Data Protection Regulation UE 2016/679). The call request is either from the patient or the family.

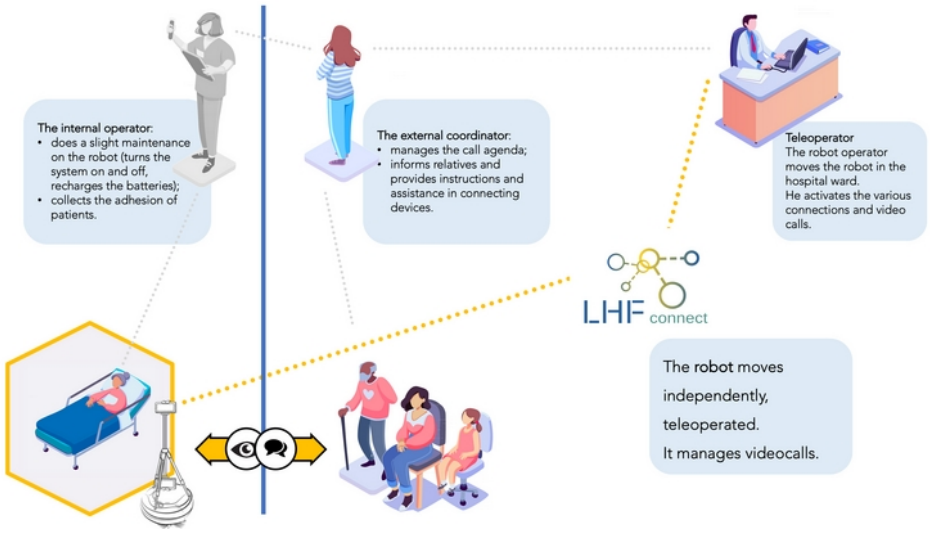

Figure 4. The LHF Connect concept.

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4. LHF CONNECT

The robot hardware is a system consisting of a mobile base (vacuum cleaner robot), a tripod (photo stand) with video communication tools (tablet PC, cameras, speakers) onboard, with an open-source software based on multi-platform web technology. The system does not require any specific competence to be assembled and teleoperated. The estimated cost per purchase of hardware is 1,200 €. The prototyping carried out so far has been possible thanks to the use of a commercial robot made by iRobot, who provided access to internal control routines for a limited number of machines. One of the challenges encountered during testing was the wi-fi connectivity inside hospitals. LHF Connect now provides very robust communication protocols to travel across halls and rooms, switching from an access point to access point and overcoming local holes in the network, which are always present.

The first two weeks of the LHF Connect design phase passed while trying different models of vacuum robots and developing the software, the user interface, and the communication protocols. On April 9th, 2020, LHF Connect entered the hospital to be illustrated and tested with doctors and sanitary staff.

A major limitation of LHF Connect was the lack of arms and hands to interact with the environment: in some hospitals, rooms had closed doors: in this case, LHF Connect would have to ask a nurse to open the door.

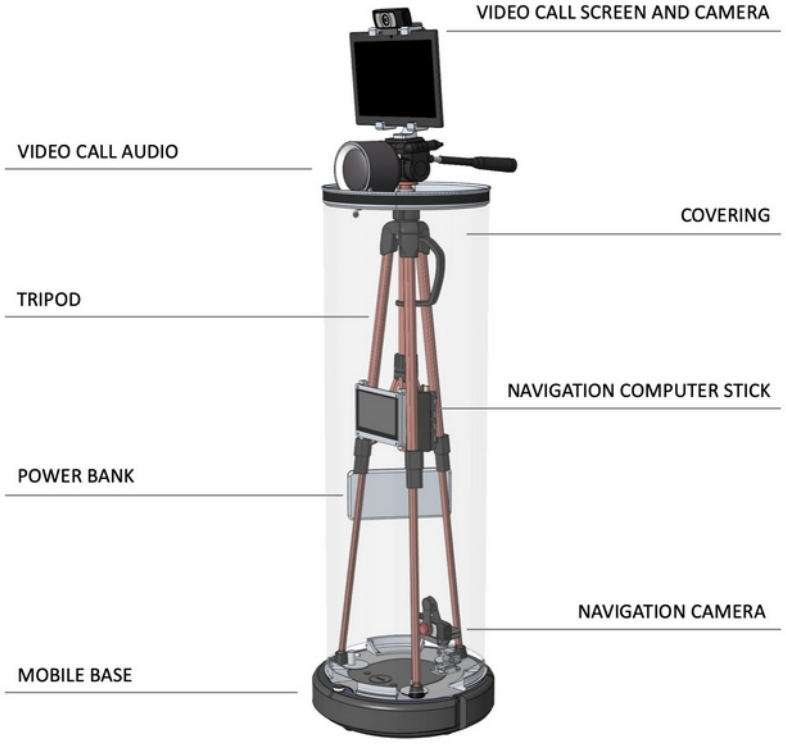

Figure 5. The LHF Connect teleoperated robot.

4.1. An Opensource Project With Many Fields Of Application

Since LHF Connect is an opensource project, all instruction to assemble hardware parts are accessible; the software, developed for this specific purpose is freely downloadable. LHF Connect was promoted in local communities and sanitary institutions and the team offered support to replicate the robot and customize the service.

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Beyond the global pandemic, LHF Connect has met the interest of the health care environment mainly, in particular hospitals with long stay wards, infectious diseases or where fragile patients are present. Moreover, the project found interest from nursing homes for elderly persons and residences for persons with disabilities.

4.2. Service Design, finishing and further assessments

The service blueprint proposed for the first trials was composed by the "Call cycle" and the "Daily routine". As it's possible to observe, patients are not actively involved during the whole process to simplify their participation. Core activities are leaded by an external coordinator and a volunteer who teleoperates the robot. In particular, service design allows to operate inside hospital departments without being physically there. This gives external operators (volunteers) the possibility to concentrate in communicating and encounting patients and relatives with the care needed. Other design goals were meant to reach some advantages (cfr. 3.2).

Moreover, LHF Connect project has great customization possibilities. Service blueprint could be customized, the hardware could be assembled and finished in different ways: in terms of aesthetics, but also to ameliorate its functionality. Finally, the robot could be implemented for other purposes. Future developments of LHF Connect will deal with contextual needs research in collaboration with national associations operating in hospitals. This activity is meant to conduct co-design sessions to test prototypes in the field. Moreover, we will conduct experiments to reveal the social and emotional role played by the robot in the hospital (Alves-Oliveira *et al.* 2015) also characterising final aspect and finishing (in particular for kids environments). These goals are possible thanks to a national research funding won (on November 2020, Fondo Integrativo Speciale Per La Ricerca (Fisr), Avviso Per La Presentazione Di Proposte Progettuali Di Ricerca Finalizzati Ad Affrontare Le Nuove Esigenze E Questioni Sollevate Dalla Diffusione Del Virus Sars-Cov-2 E Dell'infezione Covid-19).

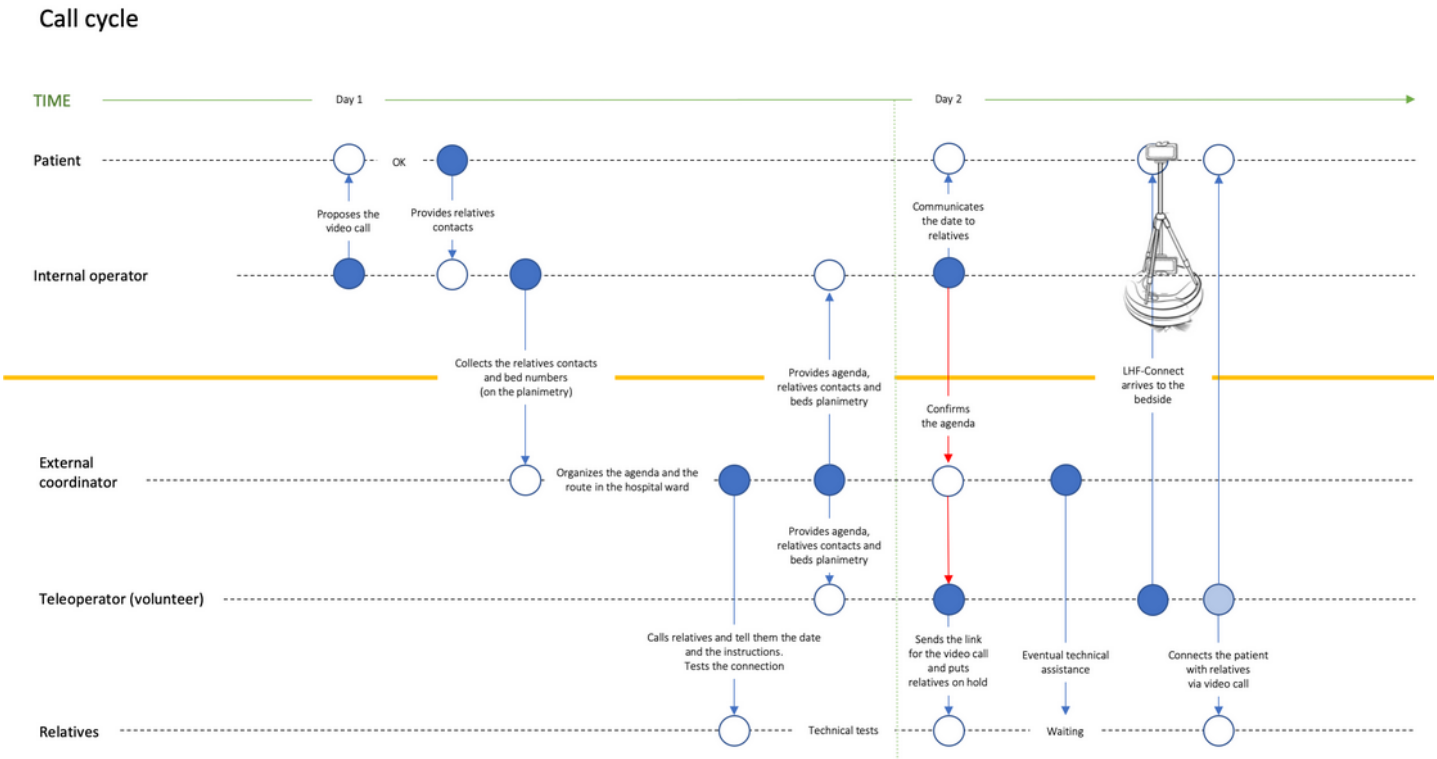

Figure 6. The LHF Connect call cycle (service diagram).

4.3. The Apuane Hospital Experience (Massa)

On April 9, 2020, thanks to the collaboration and interest of the hospital staff, the first LHF Connect prototype was tested inside a non-COVID-19 department within the Apuane hospital (Massa). The trials carried out in the department were successfully completed, the remote control did not show insurmountable difficulties, despite the problems related to the discontinuity of the internet connection used for the purpose. The robot tested a video call with a patient, without particular obstacles. The experiment was attended by some of the members of the robot development team, as well as by doctors, nurses and privacy experts.

LHF Connect met the enthusiasm of the medical staff who showed interest in continuing the experimentation by modifying the service design: this department has expressed its willingness to experiment the robot with a nurse teleoperating the robot from inside the hospital, to guarantee total respect of privacy norms and take advantage of the consolidated knowledge in dealing with hospital patients.

Figure 7. April 9, 2020: the first LHF Connect entered the Apuane Alps hospital (Massa).

4.4.The Cisanello Hospital Experience (Pisa)

On April 10th, 2020, a second prototype of LHF Connect entered the Cisanello Hospital, in a non-COVID-19 ward, and - a few days after - in a the COVID-19 area. Testing sessions are still ongoing at Pisa hospital. In the COVID-19 ward and intensive care area, the teleoperated robot was tested for video calls between patients and relatives. The hospital staff was impressed by the robot and the service proposed. The hospital staff also proposed to test the robot for other purposes such as remote-monitoring and tele-consulting in intensive care units.

Figure 8. April 9, 2020: the first LHF Connect entered the Apuane Alps hospital (Massa).

4.5. The As.far.m RSA Experience (Induno Olona – Varese)

Local organizations have implemented robots for their guests. Among the most significant example there is the Assisted Healthcare Residence As.far.m (RSA), a nursing home in the

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province of Varese, which created an LHF Connect giving it a different body (hardware support for devices). The tablets are mounted on a plexiglass structure with two suction cup supports. This implementation fully captured the spirit of LHF Connect, which provides an open-source technology and a simplified method of realization (through products available through e-commerce), but which is suitable for transformations and customizations: the robot has been enriched with an open compartment and a shelf that allows guests to receive magazines and small objects directly in their room.

Figure 9. LHF Connect at As.far.m in Induno Olona (Lombardy).

4.6. Finishing

To ameliorate and shorten the disinfection procedures necessary fort the robot twice a day, we also studied a possible solution to cover it. Two concepts were generated, imagined as a case to be used on top the simplified solution proposed in the manuals (always buildable with commercial products available online).

The first concept developed is a cylindrical plexiglass cover (in three parts linked one to the other by iron hooks) with a dome on the top. The second concept, lighter and cheaper, uses a transparent polycarbonate compound panel held in place by plastic circular supports.

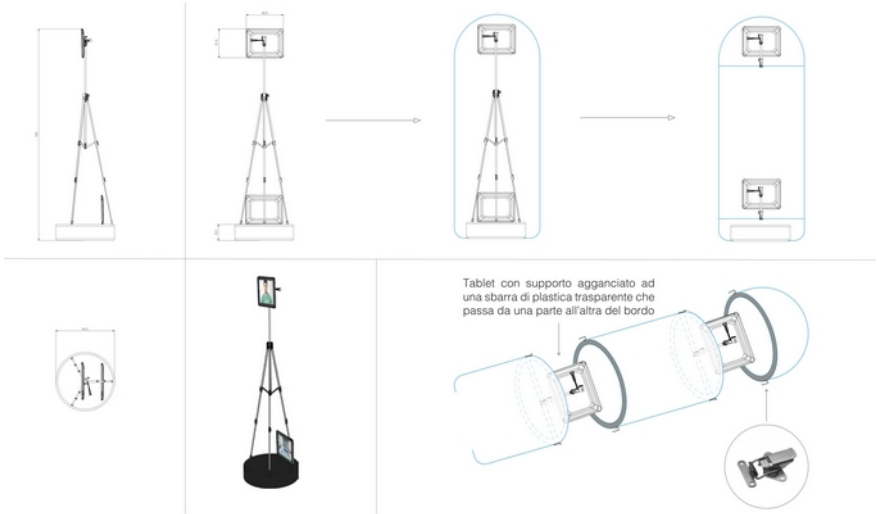

Figure 10. Concept 1 for the LHF Connect finishing to facilitate the disinfection procedures.

4.7. The LHF Connect Communication Strategy

In order to spread the LHF Connect project, it was necessary to promote it broadly to get in touch with as many people as possible throughout the national and international territory who could need and implement it in local contexts. For this reason, press channels have been used for general dissemination aiming at broadcasting high-level information in national, regional and scientific newscasts. The news has been also launched on social channels. Besides, the project has circulated on important channels for the scientific community, such as IEEE Spectrum. The website constitutes the hub where all the information is collected and where it is possible to find all data useful to replicate the system. Communication activities brought back important feedbacks from companies interested in robotic innovations. In particular, many organizations that manage residential facilities for fragile people demonstrated interest in developing teleoperated robots for different purposes, such as telemedicine, telemonitoring and tele rehabilitation.

4.8. The Website

The LHF Connect website constitutes the hub where is possible to download all manuals to replicate the robot without specific competences. The website architecture is simple and clear, divided into intuitive sections:

- **What it can do**: essentially the reason why LHF Connect was designed and its functionalities. Contents are communicated with few slides and short videos that illustrate different tasks that the robot can accomplish.
- **How it is done**: this section collects all manuals to build the robot. The section is completed with a FAQ, Anomalies management section and a specific forum.
- **Self organise** and **Operating on the territory**: sections dedicated on how it could be possible to organize an LHF Connect service and case studies realized in Italy (with a call to action – if required by the organization);
- **Gallery**: photo and video gallery that tell the LHF Connect story, since the first prototypes until the last trials.

Instructions have been designed to easily assembly the hardware: list of hardware parts needed, assembly manual, 3D model and cad files. Manuals are provided to set up the software for the robot and the remote control, control flows (Automate), Apps (Android and web app RTC), accompanied by a repository in GitHub. Instructions illustrate how to implement the service: remote control, daily management, and disinfection manuals are available on the website.

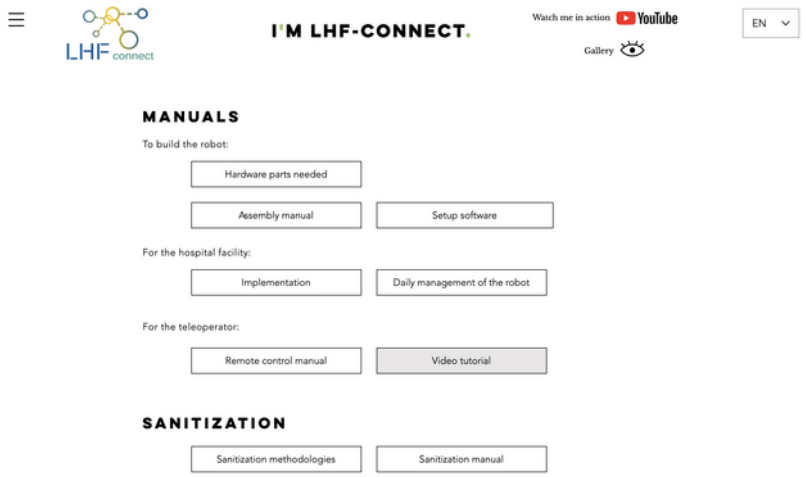

Figure 11. A screenshot from the LHF Connect website containing all manuals to replicate the robot.

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5. CONCLUSIONS

LHF Connect represents a case study where professionals coming from different fields of scientific research collaborated profitably to achieve a goal in a short time. LHF Connect established confidence in the possibility for effective robotics solution to urgent needs, such as patient-family communications in COVID-19 hospital wards. Thanks to the continuous work carried out together with different stakeholders within the hospital environment, the potentiality of a telepresence robot for different purposes emerged (as remote consultations and telemonitoring). These applications are not limited to the pandemic and will certainly be tested in hospitals in the future. Possibilities could flourish if telepresence robots would be equipped with manipulation capabilities able to interact with non-structured environments, such as the AlterEgo robot prototype. This kind of teleoperated robot could open doors, carry small objects, but also caress a person and help remote encounters to retrieve a sort of physical interaction, stimulating a renovate human-machine interaction. As noted in the introduction, virtual meetings are currently made up of the only audio and video components, while the physicality of teleoperated robots could help in interacting with the context, increasing the possibilities of use, but also stimulating the exploration of the physical component in human relationships.

Figure 12. Left: LHF Connect during a video call at the Cisanello hospital (Pisa). Right: AlterEgo shakes hands at Maker Faire Rome 2019 (photo credit: Corina Daniela Obertas).

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