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„Benefits of Applying Robots in the Context of Design Thinking Workshops“

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Abstract

The goal of this work is to explore the benefits that the usage of robots can bring to Design Thinking workshops. Reviewing real-life scenarios in domains of the manufacturing industry, health care, and education, the study suggests which benefits of robots are applicable to the Design Thinking workshops. The thesis develops an application scenario, where a humanoid robot acts as an avatar for a remote participant, making it possible for them to engage fully in the workshop activities. To demonstrate the reasonability of the scenario, a proof-of-concept implementation simulates the behavior of the remote participant who uses the NAO robot as an avatar. The work is concluded with a discussion of the potential that robots have in revolutionizing Design Thinking workshops, namely, by removing geographical barriers, enhancing the sense of presence for participants, and improving overall collaboration and Collective Intelligence.

Keywords: Design Thinking, Telepresence, Humanoid Robots, Digital Twin, Co-Creation, Collective Intelligence

Contents

1 Introduction

Design Thinking is a powerful methodology to support the exploration of innovative design ideas in the problem-solving process. Design Thinking workshops are organized to help multi-disciplinary teams find creative and non-standard solutions. The purpose is achieved by selecting storyboards as the main Design Thinking tool. The usage of tangible visualizations of the use case aspects, represented with SAP Scenes haptic paper figures, helps to encourage active collaboration and communication among the participants. As a result, it promotes Collective Intelligence and Co-Creation, which leads to discovery of more diverse and inventive solutions.

Unfortunately, nowadays, there is a limitation that Design Thinking workshops can be held exclusively when the participants are physically present.

Recently, with the emergence of Industry 4.0, robots have been increasingly used in a variety of domains. In addition, a growing number of realistic humanoid robots have been developed and presented to the public. A vivid example of them is the robotic humanoid "Ameca", presented in 2021 by Engineered Arts [1].

To support the telepresence during the Design Thinking workshops, it is suggested to apply robots to deliver a realistic experience for remote participants. The goal of the work is to explore the potential benefits that robots can bring to the workshops.

In section 2, real-life experiences of robotic usage and their most applicable functions are analyzed in the three main domains: the manufacturing industry, healthcare, and education. In manufacturing robots are utilized to perform tasks that are either dangerous or repetitive. In healthcare robots assist during surgical operations, provide transportation of supplies, and patients care. In education they become necessary tools to learn about programming and robotics. Besides, robots are used to assist during the remote learning process. Section 3 contains suggested application scenarios of robots in the Design Thinking workshop. It depicts how robots can be used to enable remote participants to take part in the workshop and its consequential benefits. In section 4, a proof-of-concept implementation is presented, in which a humanoid robot NAO simulates the behavior of a remote participant during different phases of the Design Thinking workshop. The reflexion on the program, its current and future implications are discussed in section 5. Section 6 summarizes the most important insights and conclusions of this work.

2 Theoretical Foundations

2.1 Design Thinking

Design Thinking is a problem-solving methodology which facilitates discovery of human-centered perspective solutions. It involves seeing a problem from multiple perspectives, creating rapid prototypes and actively collaborating with stakeholders [2].

It is a powerful tool for innovation that combines technological, business, and human aspects in the initial setting and final solution of the problem. Through interdisciplinary collaboration, continuous improvement, and an end-user focus, it provides creation of innovative systems, products, and services. Through fast conceptual prototyping, Design Thinking enables development in a dynamic and interactive setting [3].

Design Thinking can be approached within 5 main stages:

1. Empathize: At this stage, the focus is on searching of the target users needs, in order to analyze their pain points and motivations. To do so user research, observations, and personal interviews can be held out.

2. Define: The problem statement can be clarified once there is a solid understanding of the focus group. A clear and straightforward description of the issue from the viewpoint of the user has to be formulated.

3. Ideate: At this phase, as many solutions for the given problem as possible should be generated. There is a variety of ideation techniques, including SCAMPER, brainstorming, and brainwriting.

4. Prototype: Low-fidelity prototypes of solutions are created on this stage. These prototypes can take various forms, such as a basic sketch or a mockup created with a design tool. It is done in order to present users tangible results and to collect feedback as fast as possible.

5. Test: Finally, prototypes are put for testing by the actual users. In its turn, it leads to the assessment of the solutions effectiveness and identification of improvement points.

It is essential to acknowledge that the process of Design Thinking is non-linear. As soon as the feedback is given and more insights are collected, there is a possibility to swap the stages to learn more about the problem and its solutions [4]. The key point is to encourage creativity. Therefore, brainstorming and exploring diverse ideas should be stimulated.

There are various approaches and tools available to motivate Design Thinking. Storyboarding is one of them. It allows people to communicate their ideas with visual promts. SAP Scenes is a realization of the storyboarding concept, which presents a set of predefined illustrations that can be combined to create scenes that later form storyboards. A storyboard is a set of visual representations of the customer journey through a product or service. An example of such a scene is displayed in Figure 2.1.
Storyboards, made during the Co-Creation sessions, help to visualize and communicate ideas better. The predefined illustrations become particularly useful for focusing on ideas rather than on drawing skills.

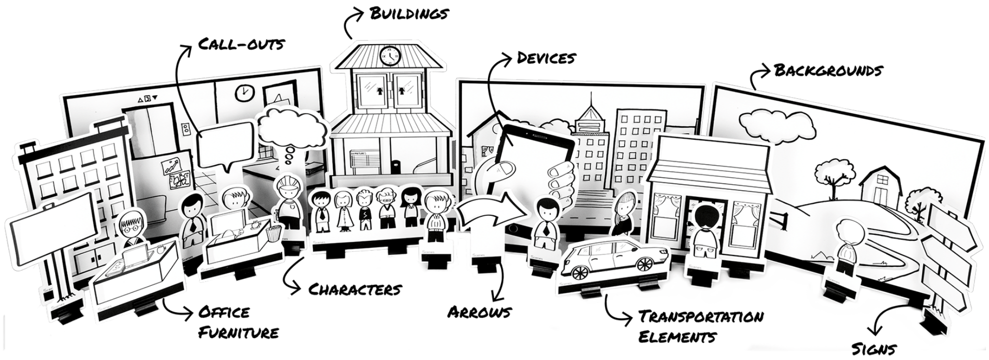

Figure 2.1: Example of SAP Scene [5]

SAP Scenes is a collection of graphical elements that can be combined to create storyboards during the empathize phase of Design Thinking and for products or services created during the ideate phase [5]. The concept of bringing together different stakeholders (in particular, users, employees, and experts) to develop solutions collaboratively is called Co-Creation. It becomes a perfect reflection of Design Thinking in the multiple perspectives of users needs. Co-Creation is the collaborative work of different stakeholders guiding the design process. During workshops diversely oriented users effectively align and provide a range of insights. As a result, designers can obtain more comprehensive ideas concerning what should be included in a product or service.

Making the most of a service design culture involves helping businesses create the atmosphere where stakeholders and design teams can easily collaborate, understand each other, and execute congruent strategies. It also entails referring to the company as a whole rather than purely focusing on the clients needs and their limited key areas. Additionally, to make use of the wide variety of perspectives, knowledge, and experience that every participant has, a well-facilitated workshop can be a efficient tool [6].

Co-Creation brings different perspectives to the discussion and actively uses Collective Intelligence. The latter is usually defined as an ability of a group of individuals to work together to accomplish a goal bigger than one could on their own. Base idea behind the Collective Intelligence is that combined intelligence of individuals with different attitudes and viewpoints helps to create solutions of greater value [7].

Thus, Collective Intelligence together with Co-Creation is a potential magnifier of

Design Thinking. It helps to find new ideas, get feedback from a large number of people, and generate optimal solutions to problems [8].

2.2 Digital Twin Interpretations

A Digital Twin is a virtual copy of a physical system that is updated throughout system life cycle. Using a Digital Twin, a low-cost prototype for testing and simulation can be created during the design phase. Digital Twins were first used in the manufacturing industry, but they are being applied increasingly in other fields. Digital Twins can be divided into two categories. The ones utilized in the design stage are essentially prototypes that make it possible to test and assess a concept at a minimal cost and effort level.

The other category functions on the usage stage. In this case Digital Twin provides a connection with the real physical system, enabling the interchange of information between them. It implies that the Digital Twin can receive information from the physical system, and vice versa [9]. Interaction between an information system and its physical equivalent is simplified while using Digital Twins. They can also assist the users in activities including scheduling and controlling physical machines in production. Furthermore, an analysis of the present system as well as insights into data from system components can be also obtained with Digital Twins [10].

In this work, the term "Digital Twins" refers to digital conceptual models that can be further processed and decomposed in order to be integrated with existing business assets. By establishing a connection between unrestricted design artifacts and more formal abstractions, the interaction between conceptual modeling and Design Thinking promotes digital agility.

Here are some common challenges of traditional Design Thinking.

- Restricted location and time availability
- Restricted number of participants
- Limitations on the modalities of tangible representation (drawing skills, haptic figures, etc.)
- Difficulty in sharing the accomplished results
- Challenges to transfer assumptions

Digital Twin can help to overcome these limitations in the following ways:

- Independence from location
- Innovation in distributed environments
- Easy adaptation of the used objects
- Knowledge is easier to transfer

2.3 Digital Design Thinking Using Scene2Model

The software application Scene2Model makes it possible to create a Digital Twin of the Design Thinking artifacts that can be shared with stakeholders around the globe, widening the features of the innovation mindset and Collective Intelligence.

2.3.1 Technologies and Functionalities of Scene2Model

The Scene2Model, which was created by OMiLAB, is a digital twinning tool applied in Design Thinking workshops, where the storyboards function as a physical base. Using the ADOxx metamodeling platform, Scene2Model allows to create a digital conceptual model that copies the physical design artifact [11].

Figure 2.2 below contains comparisons of a Digital Twin for Design Thinking with other common kinds of Digital Twins. The main difference is that Digital Twins used for production and systems mirror the state of the physical object. However, Digital Twin for business models enriches the digital copy and improves its conceptual design.

Conceptual modeling allows each paper figure to be digitalized, processed, altered, and annotated with additional information. Therefore, the digital model can be semantically enhanced by the statements that were formulated during the workshop.

In this context, Scene2Model offers a modeling environment for workshops that captures and stores the artifacts from SAP Scenes as a digital model [11].

Kind of Digital Twin / Features	Digital Twin in Production (Singh, et al., 2021)	Digital Twin of Systems (Kirchhof, Michael, Rumpe, Varga, & Wortmann, 2020)	Digital Twin for Business Models
Physical Twin	physical objects (existing or future)	Systems	designs of innovative scenario using tangible objects
Digital Twin	data, software	models of the system, data from a system, services for using data and models, software	conceptual models, software
Relation between digital and physical	state of physical and digital twin is mirrored	data integration from the system and invoking services	enrichment to improve conceptual design
Operations	control planning and execution of physical systems, analysis	control and analyse systems, integrate system components	aggregate and enrich information, fast prototyping, input for further usage, support design process, documentation
Software tools	e.g., Azure Digital Twins[1], Webots[2]	e.g., MontiArc[3], ROS[4]	e.g., Scene2Model

Figure 2.2: Different kinds of Digital Twins compared with Digital Twin for Design Thinking [11]

2.3.2 Digital Twins for Design Thinking with Scene2Model

During the Design Thinking workshops, participants create storyboards manipulating SAP Scenes paper figures to visualize customer journeys, product use cases, processes, etc. These storyboards and other tangible artifacts are called haptic Design Thinking

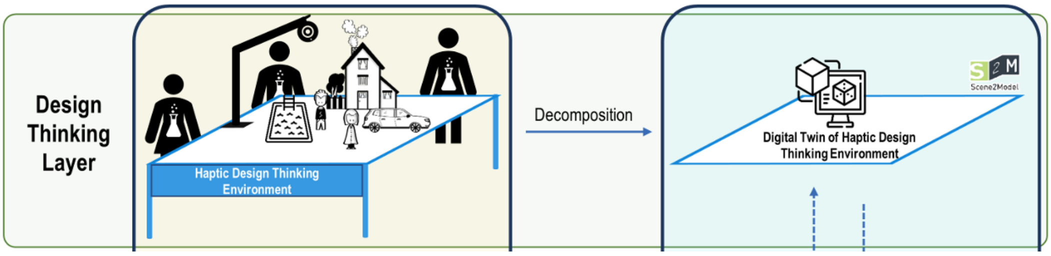

Figure 2.3: Results of the Design Thinking workshop [12]

environment. They are utilized to collect and register the ideas with a focus on Co-Creation and fruitful communication among participants. To support the decomposition of the storyboards into their basic elements, the OMiLAB community offers Scene2Model, a unique tool that automatically converts physical scenes created throughout workshops into Digital Twins of the haptic Design Thinking environment [12]. The semantic concept of Digital Twin is used on the Design Thinking layer, as visualized in Figure 2.3.

Digital Twins consist of digital representations of the physical artifacts that can be enriched semantically to help the aggregation of collected knowledge. As it was mentioned above, they go beyond being only digital duplicates of the physical artifacts created during the workshops.

These representations contain implicit knowledge associated with the interpretation of tangible artifacts. Moreover, the digital models enable knowledge to be captured, processed, and analyzed. This is made possible by the models' incorporation of paper figures, which not only act as instances but have classes assigned to them. These figures provide crucial context information that makes the processing of the models easier.

To summarize, new business ideas are collected through haptic Design Thinking workshops on the Design Thinking layer. The physical results of the workshops are SAP Scenes that represent use cases and ideas. Afterward, these scenes are decomposed into Digital Twins, which are conceptual models that can be modified and improved later by means of the Scene2Model tool [12].

2.4 Application of Robots in Different Domains

2.4.1 Application of Robots in Manufacturing Industry

In modern industrial setups, robotics technology has been effectively applied to take over tasks that are non-ergonomic for human workers. For example robots are widely used while working with heavy objects or adverse conditions, and in cases involving high risks, e.g. manipulating hazardous materials. Robots are commonly replacing workers in repetitive operations as well as in those ones that require high precision [13]. In manufacturing usage of robotics technologies can be extremely beneficial, above all it improves reliability, precision, and flexibility. Robots also can work continuously without a human error factor, which minimizes waste and leads to a solid return on investment.

For instance, the combination of machine vision and robotic arms, a quality check is higher, because it becomes possible to detect minor defects or differences in coloring of the product.

Other examples of industrial tasks, where the robots are most effective, are the following [14]:

- Welding: Due to cameras and lasers, robots can perform high-precision welding.
- Sealing and adhesive application: Robots can perform precise dispensing and application of the substance.
- Assembly, screwing, and handling: Due to its strength, robotic hands can perform quality and fast assembly/handling of spare parts.
- Picking, packaging, and palletizing: Robots can perform monotonous tasks and streamline logistics with minimal errors.

The Internet of Robotic Things (IoRT)

Traditionally, the Internet of Things is a network of embedded with sensors electronic devices, which via the Internet supports their communication and data exchange. The IoT is aimed to improve services of the devices and is available anytime and by anyone [15].

The wide usage of the IoT led to its integration with robotics, known as the Internet of Robotic Things. The IoRT allows robots to track the environment, analyze the data from sensors, and act accordingly, which makes them more autonomic. This merge of technologies is essential for production efficiency, self-correction, and continuous improvement [14].

Collaborative robots

Traditional industrial robots are typically meant to be enclosed for people's safety. This separation may lead to certain limitations. For this reason collaborative robots, or cobots, have been recently created. These robots have been specifically designed for safe and efficient human-robot interaction. And they have been meant to share workspaces with humans [16].

Cobots, as illustrated in Figure 2.4, are made to be more compact and specialised than industrial robots. Various niche companies develop them to offer robotics advanced capabilities to smaller businesses. Nowadays, they are getting more popular and widely used because of more affordable computing power and sensor costs. The advanced algorithms enable cobots to analyze their surroundings and adjust to the transforming conditions, making them perfect for tasks that require exclusive adaptability and agility.

What is also important is that these robots may offer real-time decision-making, due to their adaptability to changing data and surroundings. In addition, they obtain new unique features. Thanks to boosting improvement in sensors characteristics and AI

Figure 2.4: Examples of collaborative robots [16]

integration, modern robots perform unreachable tasks for humans. The current focus of the collaborative robots market is to design robots that can be fast and efficient in solving problems, thus providing a quick return on investment. The main focus of cobots as a concept and its core goal is to enhance worker safety and well-being [17]. Machine vision, IoRT, and cobots are now changing the manufacturing industry. These technologies are helping to achieve exceptional flexibility, quality, and adaptability for enterprises of different sizes.

2.4.2 Application of Robots in Health Care

Robotics can be applied in many medical practices, such as surgery performance, patient consultation, rehabilitation, and everyday care-taking. Robots are instruments aimed at supporting and simplifying the work of medical personnel rather than replacing them.

The COVID-19 pandemic popularized remote-control robots, mostly they were used for delivering items to patients, e.g. food, medicine, etc. [14] Robots have become an integral part of the medical field and are now considered to be a standard practice. Kinematic systems assist surgeons in invasive interventions and tend to increase the success of the operations. One of the common instruments, in this case, is cobots, as they are controlled easily and help to perform surgeries safer and faster [17].

Telerobots

Telerobots are actively supporting the medical domain, especially during diagnosis and operations. One type of such robots is a telemanipulator. It can be used in surgery to provide high-quality operations for people remotely, which makes the collaboration of medical experts possible, even is they are separated geographically. There are many robotic systems that are created for surgeries and the majority of them remind hands with different functionalities. The most popular and widely used is the Da Vinci Surgical

System, which is visualized in Figure 2.5.

Figure 2.5: Da Vinci Xi surgical system [18]

Telesurgery is commonly performed by two groups of surgeons. One group observes the patient's state, and the other one conduct the operation remotely with the help of a specialized robot. In case of emergency, the first group can stop the tele-assisted surgery and continue it in a classical way [19].

Telepresence Robots

Telepresence robots also started to be commonly used during the COVID-19 pandemic to mentally and emotionally support isolated patients or to perform a brief daily check-ups. Such robots look like portable computers on wheels and can provide audio and video communication.

Figure 2.6: The operation of Pudu robot inside the clinical hospital of the University of Chile [20]

During the pandemic, the usage of Pudu from the University of Chile, seen in Figure 2.6, showed that the robot can successfully move across different hospital areas. The robot is designed to approach hospital wards to allow patients to be seen by the doctors avoiding physical contact and contamination hazards. Integrated speakers and microphones provide audio communication between the doctors and the patients. The robot also has sensors to define when to stop if coming to any obstacle or the hospital workers are crossing the path. Therefore, these robots gain more independence and flexibility [20].

2.4.3 Application of Robots in Education

In the past years, the European Commission set computer technologies in schools as one of the top priorities for teaching, to help students develop the skills that are vital in the contemporary world. It became an influential tendency to involve electronic devices, including robots, at schools to improve the learning process, as well as, to teach robotic and programming skills [21]. The COVID-19 pandemic has increased the demand for remote collaboration systems. One of the solutions to this matter would be a robotic camera system named Periscope. It was created to support the scenarios where experts help workers in remote assembling and repairing tasks. As an example, the field technician can ask an expert for advice on how to repair specific equipment or mechanisms [22].

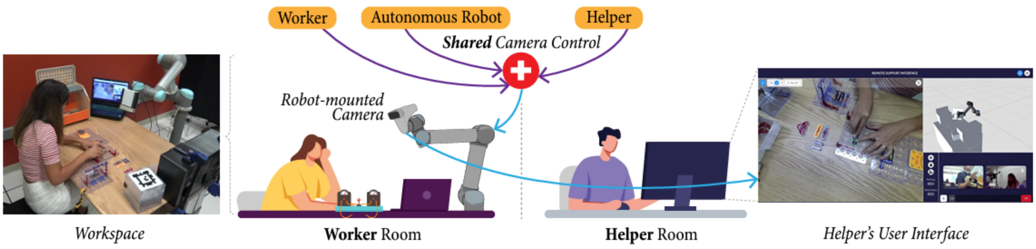

Figure 2.7: The Concept of Periscope camera [22]

Periscope is a robotic camera system that enables remote collaboration on a physical task. As illustrated in Figure 2.7, the remote helper can see the workspace with the help of a robot-mounted camera. The camera can be adjusted and controlled by both sides.

The system is beneficial by providing shared visual information of good quality that is flexible and can be easily adjusted, which, in its turn, is enhancing verbal communication and the process of coordination. It helps to overcome the main obstacles of remote communication, which are isolation and disconnection. Such a result is reached by the high flexibility of the system and the possibility of being manipulated by all participants.

The system creators had the following goals [22]:

- Versatility of camera views to support different activities
- Intuitive camera control
- Dual-user interactivity for modification of the camera view

- Congruity to regulate users' communication and independent behavior to achieve common ground
- Usability to support general communicational and functional requirements.

In recent years, the robotics industry made major progress in creating robots capable of collaborating with humans in many different ways. Humanoid robots, such as NAO, are used in fields, ranging from medicine and education to entertainment and scientific research. Yet, the success of a robot depends heavily on its relevant, meaningful, and simple communication with humans.

The NAO robot is a humanoid robot developed by SoftBank Robotics. The robot is 574 mm tall, has a human-like appearance that includes a head, torso, arms, hands, and legs. It was designed with focus on human-robot interaction. NAO can be programmed using Python, C++, and its proprietary language, Choregraphe. The robot is able to walk, recognize faces, objects and facial expressions, detect sounds, speak and perform various gestures.

The NAO robot is equipped with different kinds of cameras, sensors, actuators and LEDs, making it capable of a wide range of interactive behaviors and movements. A detailed technical overview is provided on the official documentation website [23].

For vision NAO uses two video cameras that are placed on its forehead and mouth and provide a up to 1280x960 resolution at 30 frames per second. Four microphones integrated into its head allow NAO to detect and locate sound sources and perform speech recognition. To produce audio signals the robot has a stereo broadcast system that consist of two loudspeakers in its ears.

In terms of movement, NAO is powered by actuators that control its 25 degrees of freedom, allowing a wide range of motion. These actuators are embedded in its joints, including the neck, shoulders, elbows, wrists, hips, knees, and ankles. This extensive range of motion enables NAO to walk, grasp objects and gesture. Furthermore, tactile sensors on NAO's head, hands, and feet enable it to detect a touch. For additional obstacle detection and depth perception, NAO also utilizes sonar sensors.

The interactive experience with NAO is further enhanced by integrated LEDs, which provide visual feedback. The robot's eyes, ears and feet are equipped with LEDs that can display a spectrum of colors, indicating different states such as emotions, notifications, or operational statuses.

The following case, depicted in Figure 2.8, describes the application of the NAO robot for remote sports training. The case aimed to help isolated people learn new sports activities. The humanoid robot was a good solution as it could show the movements and speak to the participants, so it became a fair replacement/avatar for the trainer.

As shown in Figure 2.9, via a simple graphical user interface, the remote operator can manipulate the NAO robot and observe the training environment using the life video and audio streaming. There are multiple actions to be performed: speaking with participants, moving the robot using walking commands, and executing the predefined exercises.

The results have shown high engagement in the learning process and a decent life interaction between both sides. Participants were well-motivated and had less social

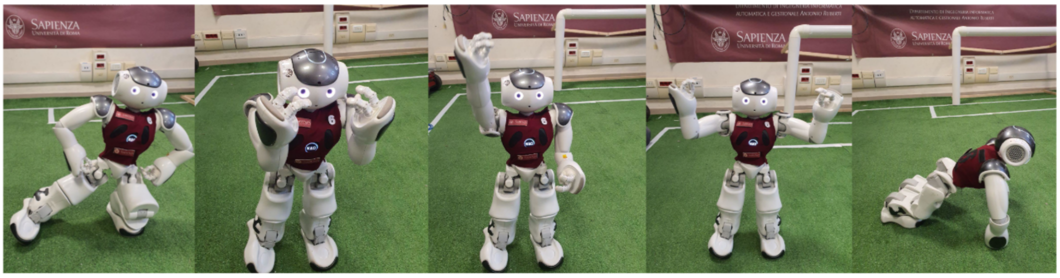

Figure 2.8: Poses of the NAO robot during exercises [24]

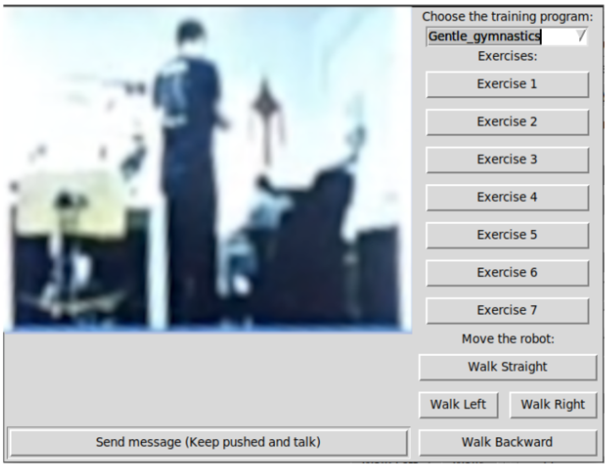

Figure 2.9: Graphical user interface the NAO robot operator [24]

anxiety while performing the exercises [24].

Another way to provide a remote task collaboration can be an Augmented Reality. AR is a display of an otherwise real environment, extended with virtual elements [25]. To apply the virtual objects onto real environment, it is common to use special software and equipment such as AR headset. A concept of Mixed Reality is related to AR and often is applied utilizing the same hardware.

Even though fully digital systems are already actively used in education, they are not suitable for collaborative manual activities. Illustrated in Figure 2.10, CARDS is a Mixed-Reality system that unites digital and physical objects in the actively collaborative learning space.

CARDS are paper cards with QR codes, that serve digital elements, e.g. pictures and videos, as physical proxies. The cards are moved easily and are useful during collaborative tasks, such as the selection and organization of the items. It is also possible to create connections between the cards using the interactive pen. The connections can have labels and be of different colors.

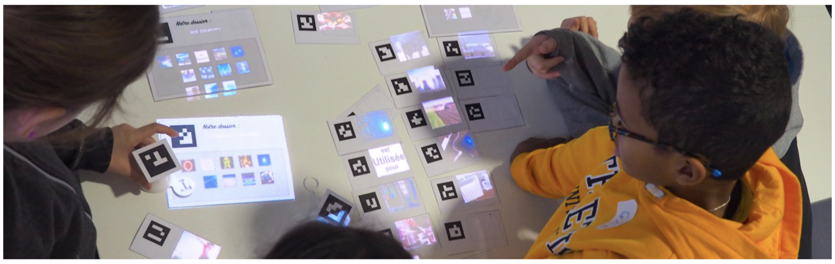

Figure 2.10: Example of CARDS usage [21]

The hardware that supports the system consists of several devices: a projector, a camera, and a computer, connected by an aluminum profile structure to the table edge [21].

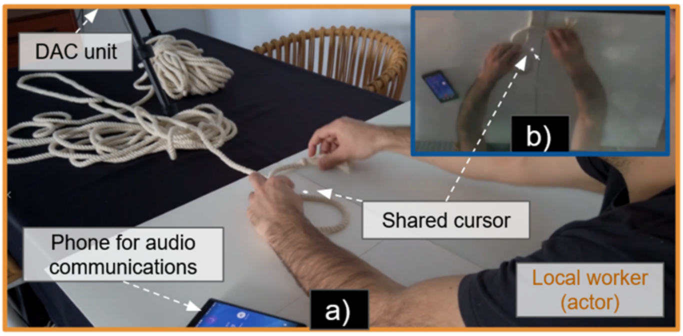

Figure 2.11: DAC Experimental setup. a) Local user workspace. b) View of the remote helper [26]

A further possibility to introduce AR into education and remote collaboration is a Distant Assist Cursor (DAC) system. The key benefits of this system are that it is accessible, simple, user-friendly, and easy to set up. The idea behind the DAC system is to use a laser cursor to support a remote helper in guiding a local user during a certain task, for example, to make a sailor knot. During the example experiment, that is described in Figure 2.11, the users were communicating via audio call and the DAC system that provided a video stream and the cursor controlled by the helper. In ten minutes, participants managed to create two knots. Distant Assist Cursor is a fast, lightweight AR system designed for remote collaboration and aimed at beginner users. The results of the experiment demonstrate that the DAC is both user-friendly and intuitive [26].

3 Combination of Robots and Design Thinking Workshop

During a Design Thinking workshop, the collaboration of the participants and Collective Intelligence play a key role. At the moment the workshops are being held with the physical presence of the participants, and this fact can be considered a barrier. To make the workshops more accessible and inclusive, using robots is suggested. We believe that quite soon interaction between robots and humans will become common practice. Technological progress in the robotics sphere will gradually help to overcome fundamental human limitations. Removing the geographical barrier, robots have the potential to transform Design Thinking workshops and provide the remote participants an enhanced sense of presence. There are two main types of tasks that should be considered when setting up remote collaboration for the workshops. Firstly, it is aimed at communication in visual and audio formats, which will enable the participants to hear and see each other and have a decent overview of the workspace. Secondly, robots will gain the ability to move the SAP Scenes paper figures in order to contribute to the creation of storyboards.

3.1 Possible Application of Robots for Design Thinking Workshops

The suggestions of how robots could facilitate the remote collaboration are listed below.

1. Visual and audio communication:
   - Humanoid Robot (NAO) may act as a physical avatar for the remote participant and provide the fullest possible presence.
   - Camera Above the Table and Laptop provide the table view, as well as, broadcasting the video and audio signals from other participants. The main limitations here are the impossibility to change camera's perspective and high dependency on the people holding the workshop.
   - Robotic Camera (Periscope) can compensate limitations of the traditional camera. Periscope is characterised by innovative features, is more flexible and can be operated by a remote participant, which results in a better feeling of presence and interaction.
   - Telepresence Robot (Pudu) is good tool to move in the location where the workshop takes place. It improves interaction between physically present participants and those who take part in the workshop remotely. Change of the

perspective and camera flexibility enhances participant involvement into the workshop activities.

2. Ability to move figures:
    - Humanoid Robot (NAO) may act as a physical avatar for the remote participant and control robotic hands manipulating with the paper figures. The possible limitation of this robot may be the need of extra space for movements, as its hands are quite short.
    - Robotic Hand (DoBot) above the table might be a flexible and effective tool, as it can perform precise operations with various little objects.
    - Car Robot (MBot) may be used to represent a figure. It is a dynamic and well-controlled option, under the term that all the figures are represented the same way and there is enough space on the table for a large amount of MBots.
    - Project SAP figures on the table is similar to what we described in the example of CARDS, it is possible to use AR instead of actual paper figures. If there is hardware that is programmed to project multiple figures simultaneously and move them, it might become an engaging mixed-reality experience for the workshop participants. Furthermore, it might be easier to introduce the remote people in this scenario, as all the users will manipulate the figures not directly, but via applied software.

One more possibility to improve remote collaboration could be in the usage of laser pointers, such as DAC. This simple technology could potentially improve accessibility and involvement of the remote participants in the discussion and creation of use-case scenarios. Pointing at figures while developing ideas and concepts might significantly widen the user experience for all participants because this behavior imitates human way of communicating in real life.

3.2 Overview of Robot Usage Benefits

Based on the real-life experiences of robot usage in different domains and their benefits, some recommendations of how robots may be applied in the context of the Design Thinking workshops were made. The benefits in the aforementioned domains are listed in Table 3.1.

The main focus is to define the prior tasks that have to be supported and the types of robots that are available on the market. Comparing with the pros from the other domains, this section contains the conclusive benefits that robots can potentially bring to the workshops.

1. Removing geographical barriers: distant people can participate and collaborate.
2. Psychological benefits: better concentration on interaction than via digital tools and reduced anxiety.
3. Enhanced sense of presence.
4. Flexibility in manipulation with physical objects (e.g. paper figures).
5. Flexibility in room navigation and viewpoint.
6. Reducing workload of workshop staff: no need to provide visual and audio context (e.g. holding a laptop) and move the figures.

Domain	Industry	Health Care	Education	Design Thinking Workshops
Benefits	1. Safety 2. Precision and Quality Control 3. Time Efficiency and Productivity 4. Return on Investment (ROI) 5. Task Flexibility	1. Precision and Accuracy 2. Remote Mental Support 3. Remote Expertise 4. Improved Patient Outcomes 5. Reduces Workload for Staff	1. Enhanced Remote Learning Experience 2. Realistic Interaction 3. Accessibility and User-Friendliness 4. Motivation and Reduced Anxiety	1. Removed Geographical Barriers 2. Psychological Benefits 3. Enhanced Sense of Presence 4. Flexibility in Manipulation of Objects 5. Flexibility of Viewpoint 6. Reduces Workload for Staff
Enables	1. Welding 2. Assembly 3. Quality Inspection 4. Logistics Tasks (picking, packing, etc.)	1. Remote Surgery 2. Complicated Surgery 3. Remote Patient Support 4. Supplies Transportation	1. Remote Guidance and Instructions 2. Remote Teaching 3. Remote Studying 4. Mixed-Reality Collaboration	1. Remote Collaboration 2. Moving Figures 3. Participants View 4. Table View 5. Speaking 6. Hearing

Table 3.1: Overview of robot usage benefits in different domains

3.3 Application Scenario

We consider using a humanoid robot as an avatar for the remote participants of the Design Thinking workshop to enable natural collaboration between remote and on-site participants. The workshop consists of three phases: preparation, workshop and exploration.

During the preparation phase the on-site participants meet in the physical workshop environment. The environment is equipped with the SAP figures, that are later used to create the storyboards. The humanoid robot is also located within the the physical workshop environment. The remote participant, who is present in the remote workshop environment, uses an AR equipment, such as an AR headset, and the internet to connect to the humanoid robot.

Before the workshop starts, the organizers set up the humanoid robot and the remote participant connects to it. AR makes it possible to achieve a realistic sense of presence for the user, by providing an optimal perspective and movement freedom. The robot is a physical embodiment of the remote participant that enables interaction with others, expression of emotions, and change of location within the workshop environment.

In the beginning of the workshop phase all the participants discuss the use cases that later will be the base for storyboard scenes. During the discussions, the remote participant can freely interact with other participants. The abilities that the robot provides to enable remote collaboration include the capabilities to speak, hear, see, walk, move figures and express emotions with facial expressions and body language. The main goals of this application scenario during the workshop phase are to remove geographical barrier and to enhance sense of presence for remote participant, Collective Intelligence, Co-Creation and creativity.

The main aspect of the workshop is building a storyboard with SAP Scene haptic paper figures. On-site participants move the figures by hand, meantime, the remote participant uses AR to control the robot's hands to move the figures in the physical space. When the storyboard is created, the Digital Twin of the physical storyboard is generated by the Scene2Model software.

The exploration phase happens after the Digital Twin of the storyboard final version is created. This Digital Twin is saved as digital processable artifacts, which can be further developed and expanded with semantics. Afterwards, the workshop is considered to be finished.

The described application scenario concept is visualized in Figure 3.1.

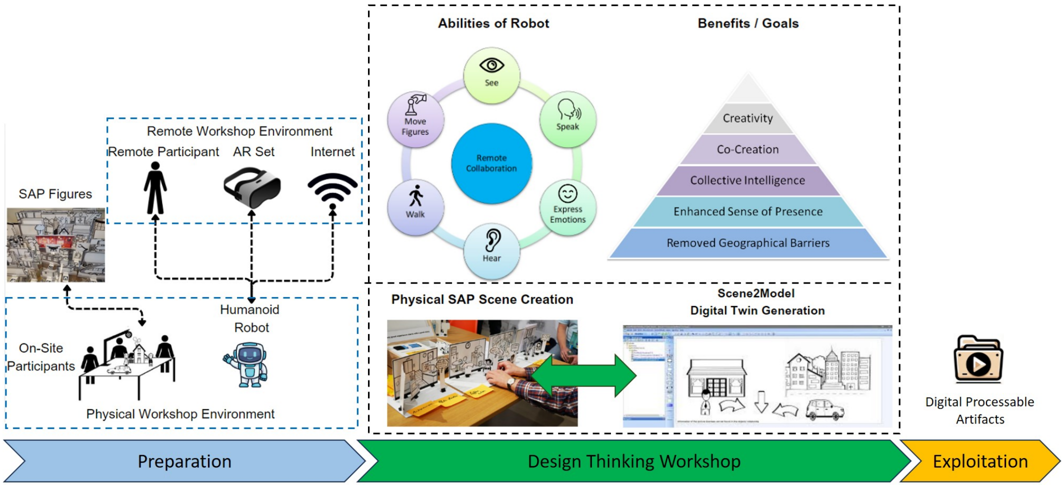

Figure 3.1: Application scenario concept visualization

4 Proof of Concept

Currently, humanoid robots similar to those described in the application scenario are in development and not yet available on the broad market. We assume that soon this technology will be advanced and avatar robots will become a common element of human everyday life. Several robots could be used to simulate the aforementioned scenario. The proof of concept is displayed in Figure 4.1.

During the preparation phase the on-site participants meet in the physical workshop environment. The environment is equipped with the SAP figures, two robots and a camera, that provides a table overview for the remote participant. The remote participant controls a humanoid robot and robotic arm from the remote workshop environment via personal computer with a dedicated for this purpose software.

Humanoid robot from Figure 3.1 can be represented by the NAO robot that may act as a physical avatar for the remote participant and support the tasks connected with visual and audio communication. Unfortunately, its hands are too short to effectively move the paper figures.

A robotic arm, represented by Dobot, has a bigger accessibility range and can help to overcome the limitation. To support its work, it is also important to have a camera above the storyboard table to ensure optimal overview for the successful operation of the robot.

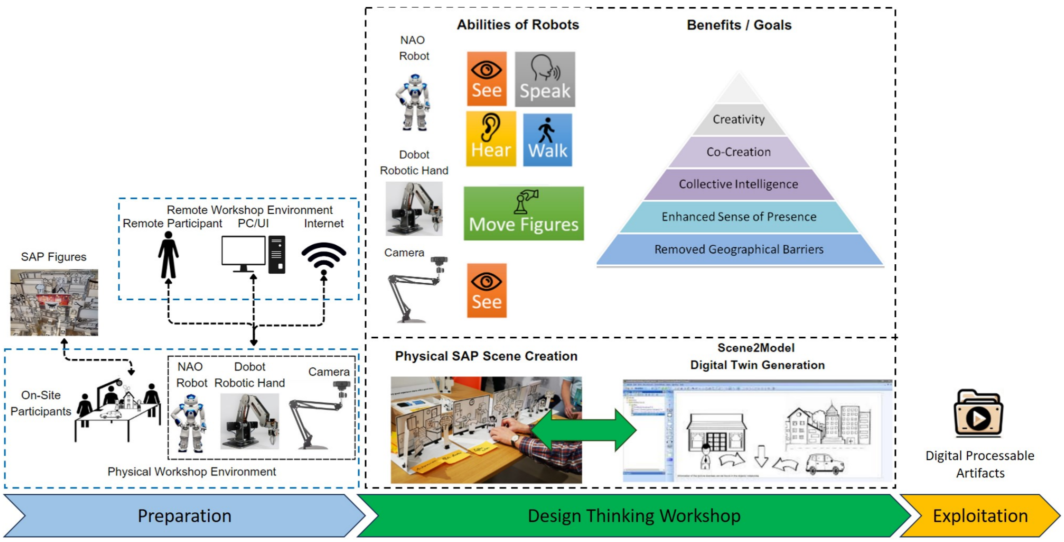

Figure 4.1: Proof of concept visualization

During the Design Thinking workshop phase participants create SAP Scenes storyboards, based on which Scene2Model software generates Digital Twins. Via NAO robot the remote participant is able to walk in the physical workshop environment, speak, see and hear other participants. By controlling Dobot robotic hand the remote participant can move the SAP figures. The proof of concept aims to achieve the same goals, that are set in the subsection 3.3.

At the exploration phase the final results of the workshop are saved as digital processable artifacts, that later can be analyzed and further developed.

4.1 Evaluation in a Physical Environment

As a part of the proof of concept illustrated in Figure 4.1, a Python-based program for the NAO robot was implemented, to simulate remote participant behavior during the Design Thinking workshop. It contains six showcases that may occur during the workshop and aims to demonstrate the abilities of the NAO robot, which are illustrated in Figure 4.2.

The the implementation proves the abilities of the NAO robot to see, speak, hear and walk, which were listed in Figure 4.1. Moreover, it was possible to enable the ability to express emotions via body language and gestures, which was suggested in Figure 3.1. In addition, two potentially useful abilities of the NAO robot, to sense touch and to recognise facial expressions, were discovered.

The timeline of the Design Thinking workshop was separated into five phases. The *icebreaker* phase is dedicated to participants getting to know each other and preparing to work on the use cases. It contains *greeting*, *acquaintance*, and *walk to the table* showcases. During the *discussion* phase, participants talk about the use cases and formulate their concepts. It contains a *use case discussion* showcase.

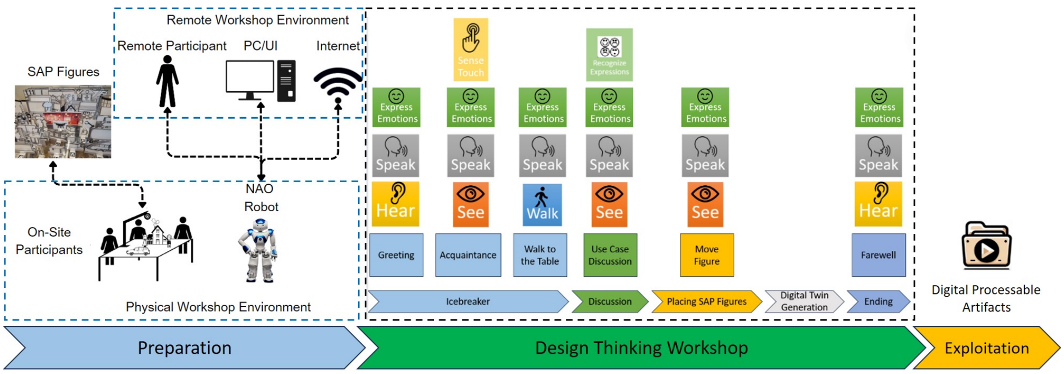

Figure 4.2: Implementation concept visualization

The next step is *placing SAP figures*, where the SAP Scenes based on the concepts from the previous step are created. It contains a *move figure* showcase. *Digital Twin generation* phase does not contain any showcase, because it is performed automatically and does not require any involvement of the participants. The final *ending* phase is dedicated to the end of the workshop, where the participants give positive feedback to the work and part with each other. It contains a *farewell* showcase. To be able to run the program on the NAO robot the following requirements have to be met:

- Choregraphe version: 2.8.7.4
- Python version: 2.7
- Naoqi version: 2.8

Important note: To be able to run the program on the NAO robot, both the robot and the PC have to be connected to the same network.

4.2 Showcase Description

4.2.1 Greeting

After the preparation phase is finished and the Design Thinking workshop begins, the participants greet each other and have a small talk. The *greeting* behavior implementation is visualized in Figure 4.3.

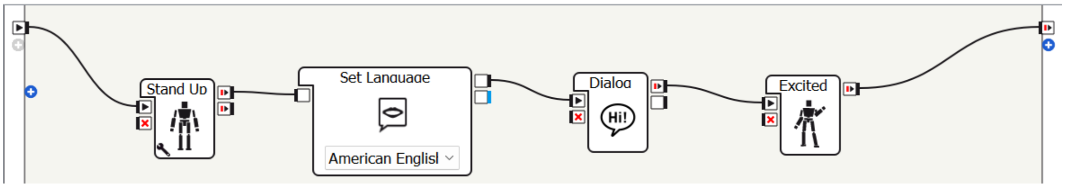

Figure 4.3: Greeting behavior

NAO robot stands up to ensure being seen and heard properly. The language of the robot is set to American English, which means the robot understands and speaks the language. Afterwards, the robot is ready to follow the predefined dialog:

- Human: Morning.
- NAO: Good morning! How are you?
- Human: Good. How are you?
- NAO: I am great. Excited about the workshop.
- Human: Me as well.
- NAO: Let's start then!

The dialog is over when the NAO robot pronounces the last phrase. As a final step, to show its excitement, the robot demonstrates the sequence of movements, such as shaking its head and hands as well as stomping actively.

4.2.2 Acquaintance

This case shows two different types of robot behavior, signaling whether it recognizes a person, that it faces, or not. The *acquaintance* behavior implementation is visualized in Figure 4.4.

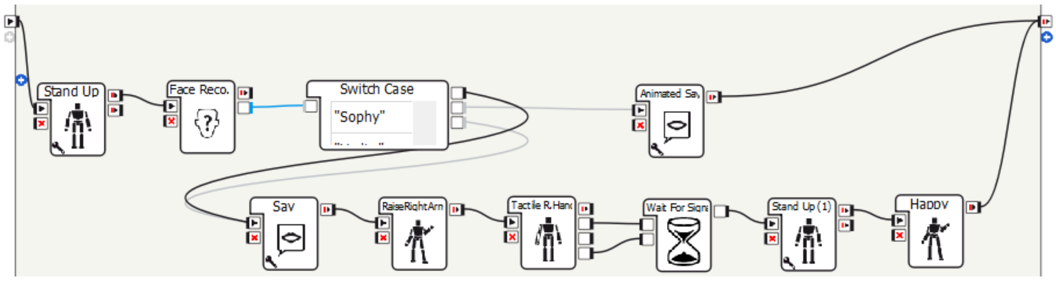

Figure 4.4: Acquaintance behavior

NAO robot stands up to ensure being in a proper position to see the participants. It activates the face recognition function, which returns a string with a person's name if it distinguishes the face. To be able to do it, the robot has to learn the face beforehand, using the corresponding command, or get it stored in the database.

In case, the NAO robot meets Sophy, the person whose face the robot already recognizes, it activates the animated say behavior and says: "Hello, my friend! Good to see you. How are you? Excited for the workshop?". This action is followed by a sequence of greeting gestures.

In case NAO faces a person and does not identify for more than 8 seconds, it offers to learn a new face. In the context of the showcase, we are only interested in simulating the behavior of a real person, so teaching the robot new faces is not the main focus. For testing purposes, we defined Vadim to be the person NAO meets for the first time. And if NAO identifies him, it says: "Hello. We have not met before. Pleased to make your acquaintance. Let's shake hands!"

Afterward, the robot raises its right hand to shake hands with the person. It waits for the hand to be touched, which means the person should press the right and the left tactile sensors of the robot's hand. When the sensors are activated, NAO puts down the right hand, and moves its hands and legs to express its happiness.

4.2.3 Walk to the Table

After the participants finish getting to know each other, it is time to head to the table with SAP figures. The *walk to the table* behavior implementation is visualized in Figure 4.5.

In this case, the NAO robot stands up to ensure a stable position for walking. Next, it moves to the table, comes to it and performs a sequence of poses that indicate that it is thinking (the robot is looking around and touching its head). After that it shows that it is 'curious' by closely looking at the table legs, while saying: "I am too short to see the figures. Please, put me up to the table." NAO raises both hands and moves its fingers

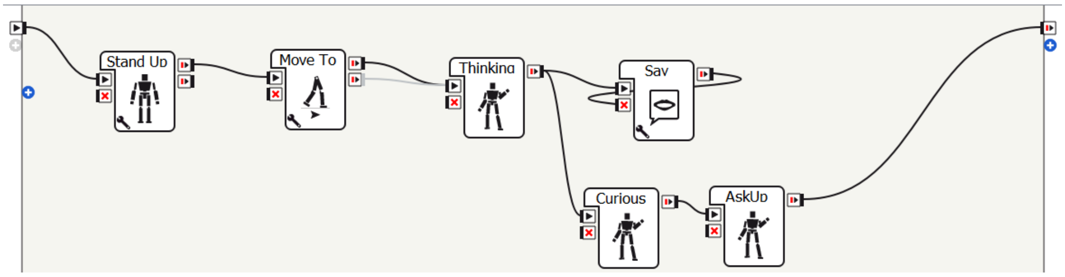

Figure 4.5: Walk to the table behavior

signalling that it wants to be lifted up to the table to observe the SAP figures. When it is done, the behavior finishes.

4.2.4 Use Case Discussion

To simulate the *use case discussions* during the workshop, there is a chance to use the ability of the NAO robot to recognize facial expressions. This ability might be potentially beneficial, which will be discussed in detail in chapter 5. The *use case discussion* behavior implementation is visualized in Figure 4.6.

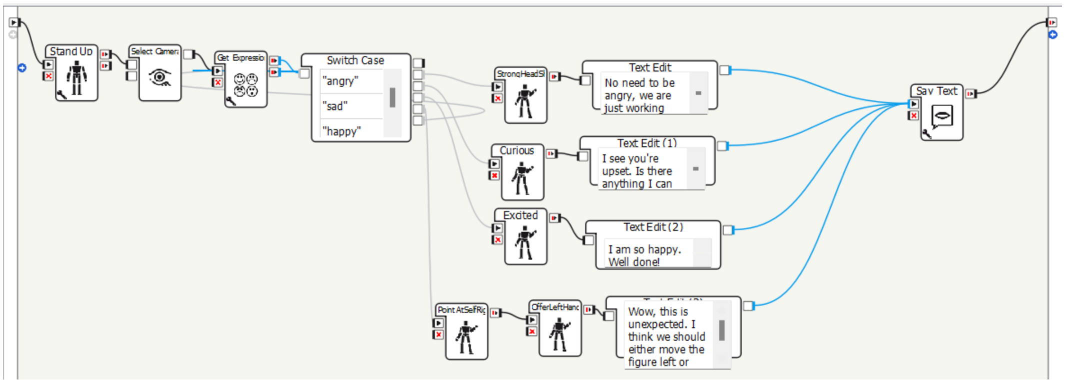

Figure 4.6: Use case discussion behavior

The NAO robot stands up to ensure a proper overview of the participants. The upper camera view is selected to allow the robot to see people's faces. The get expression function is activated and returns a string with a detected emotion. It can differentiate among five emotions, described by the adjectives: neutral, happy, surprised, angry, and sad.

Depending on the emotion robot has different reactions. In the case of neutral emotion, the robot continues the detecting process as neutral emotion does not express anything. If it detects that the person is happy, the robot expresses excitement and says: “I am so happy. Well done!”

If a person is surprised, the robot points at itself and alternately opens both hands, saying: "Wow, this is unexpected. I think we should either move the figure left or remove it completely." In this way robot assumes that during the discussion the participants came to an unexpected result and the remote participant offered a solution.

In case a person is angry, NAO shakes its head and spreads its arms, saying: "No need to be angry, we are just working here." It implies to show how a remote participant might have solved a conflict situation.

Finally, if a person is sad, the robot looks 'curious' and says: "I see you're upset. Is there anything I can do to help?"

4.2.5 Move Figure

The case shows the behavior of the remote participant ready to move an SAP figure. The *move figure* behavior implementation is visualized in Figure 4.7.

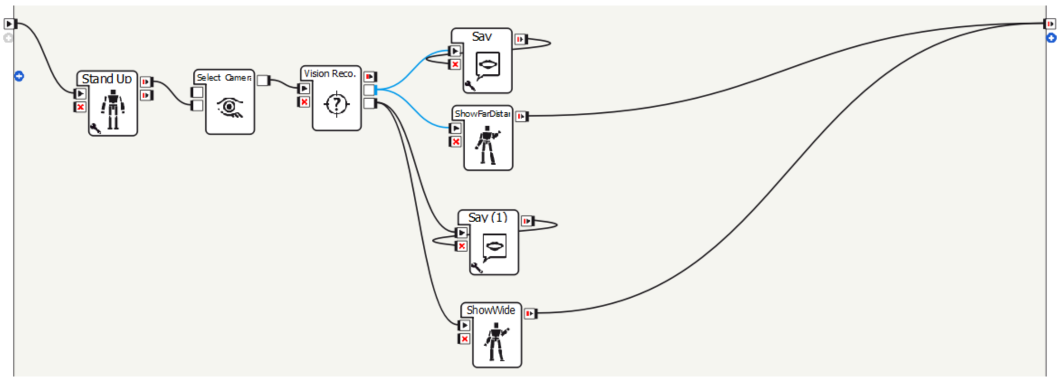

Figure 4.7: Move figure behavior

The NAO robot stands up and selects a lower camera, to ensure a good overview of the table. Next, it activates the vision recognition function to detect the objects it has in its memory database. If the detected figure is known the function returns its name as a string and the robot says: "I see the figure! Please move it for me. My hands are too short." asking for assistance. Simultaneously the robot points at the left corner of the table to show where the figure has to be moved.

If no figure is recognized, the robot says: "There are not enough figures. Please, bring more SAP figures to the table." At the same time, it shows the whole table and shakes its head with disappointment.

In this case, NAO uses its object recognition function to spot the desirable SAP figure. However, it does not show very good results with the paper figures due to the quality of the integrated camera. It can recognize only the figures which are in the vicinity.

4.2.6 Farewell

At the end of the workshop, the participants bid each other farewell. The *farewell* behavior implementation is visualized in Figure 4.8.

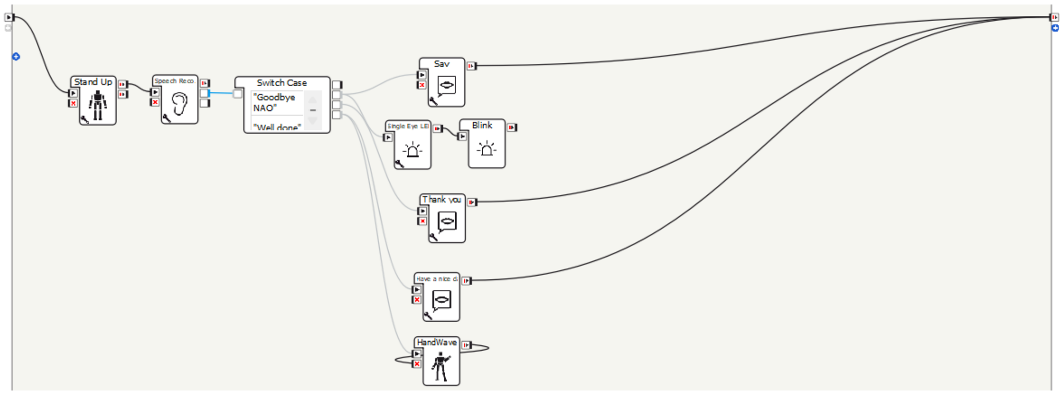

Figure 4.8: Farewell behavior

NAO robot stands up to ensure being seen and heard properly. It activates the speech recognition function to recognize the words from a list set in the parameters.

There are 3 defined phrases that the robot can recognize:

The phrase "Goodbye NAO" leads to the robot saying: “Good job, everyone! See you!”, while changing its left eye to a yellow color and blinking once. The usage of eye LEDs can potentially be interesting visualising the emotions by more developed robots.

The phrase "Well done" leads to the robot saying: “Thank you! It was nice to work together!”

The phrase "Have a nice day" leads to the robot saying: “Have a nice day! You worked well!” making the goodbye wave gesture.

5 Discussion

The previous chapter was dedicated to the technical aspects of the NAO robot behavior implementation and its capabilities. This discussion chapter is aimed to shift the focus towards the wider implications and potential future opportunities of the application of humanoid robots in the context of Design Thinking workshops. By analyzing the benefits and limitations of the implementation, we can gain insights of how humanoid robot like NAO is able to enhance remote collaboration among the workshop participants.

5.1 Reflection

Nearly all the functionalities of the robot outlined in section 3.3 were successfully implemented, except for the ability to move the SAP paper figures. The showcases demonstrated that the NAO robot can see, hear, speak, express emotions, and walk. Moreover, two extra abilities were discovered during the implementation phase: touch sensation and facial expression recognition. The implementation managed to achieve the goals of the application scenario.

However, the NAO robot is not able to show facial expressions, which has to be considered in future research. The flexibility of movement and viewpoint also need further development. The NAO robot is short and cannot support a wide and easily changeable overview, as well as, active natural walking. On the other hand, more developed robots could potentially provide agile and realistic interaction with people. As a result it might become possible for remote participants to approach their colleagues and start a conversation. Another weakness of the NAO robot is its short and stiff hands unable to move the SAP paper figures. In the dedicated showcase, it was decided to test the robot's limitation and theorize about the possible solution.

Due to these limitations of the NAO robot, the alleged flexibility in the manipulation with paper figures, as well as flexibility in room navigation and viewpoint were not achieved in this implementation.

5.2 Implication

The major benefit of the implementation is that on the basis of the showcases, we can assume how the collaboration with the humanoid robot, in the context of the Design Thinking workshop, might look like. Generally, it can be expected that people feel more excited and emotionally engaged during communication with the robot. This allows us to make the assumption that on-site participants would want to talk and interact with the remote participant more, than if they were present in a classical digital way. Physical presence of the robot makes participants not to lose focus on the remote colleague, even if an individual participant might stay inactive for a certain time. Furthermore, people would gladly help the robot if it has limitations and it is psychologically easier for the remote participant to ask for help. The robot helps to show a wide range of gestures, emotions and actions pointing at objects, which is not fully possible for the digitally present participant, who is usually only seen in the portrait area.

5.3 Future Opportunities

The NAO robot gives some inspiration for people who intend to diversify and improve their communication using techniques that are only possible through robots. For example LED lights can be used to intensify the expression of emotions. Moreover, some inbuilt functions, such as ones described for NAO in subsection 2.4.3, and artificial intelligence might help people with disabilities to overcome their limitations.

The first thing that comes to mind is movement. People who cannot walk or show gestures will now be able to participate in the workshop.

Poor hearing can also be improved by the robot. For example, it can transform audio information into the text or to recognize certain words and allow the remote participant to react accordingly as in the implementation showcase. As for speaking function, a robot can generate an audio clip from a written text, moreover, the volume of speech can be easily regulated, when needed.

The robot might also support people in seeing and recalling memories. By applying the function of object and face recognition, a robot can assist us to recollect people and things much faster. If necessary the robot can easily zoom in various objects including SAP figures, helping people with poor sight to identify them.

In case a person has trouble understanding other people's emotions and facial expressions, the robot can vividly interpret the interlocutor's feelings. It might decrease the number of misunderstandings, make people more emphatic to each other and improve the level of communication.

Finally, due to the tactical sensors on the robotic bodies, the touches can potentially be transmitted to a person, which allows to experience an enhanced sense of presence for the remote participant. It can be also beneficial to the physically present participants, as the implemented Acquaintance showcase demonstrates. The ability to shake hands with a remote participant creates a better sense of connection and a more realistic human experience.

6 Conclusion

The main goal of the work was to explore the benefits of robot usage for remote Design Thinking workshops. General principals of robotics in domains such as manufacturing industry, health care, and education have been considered. Six major benefits why robots may be applied in the context of the workshops have been suggested.

1. Removing Geographical Barrier
2. Psychological Benefits
3. Enhanced Sense of Presence
4. Flexibility in Manipulation of Physical Objects
5. Flexibility in Room Navigation and Viewpoint
6. Reducing the Workload of Workshop Staff

As a result, the concept of an application scenario was created. The idea is to use a humanoid robot as an avatar for the remote participants of the Design Thinking workshop to enable collaboration between remote and on-site participants. Usage of robots during the workshops improves Collective Intelligence, by letting more people take part in the Co-Creation process. In the proof-of-concept scenario, it was suggested to use the NAO robot and Dobot in combination with a camera. However, it should be taken into account that a modern humanoid robot that can autonomously support all the desired functionalities is not yet developed.

The implementation of a Python-based program for the NAO robot makes it clear that the main aim of removing a geographical barrier for the workshop participants can be achieved. Moreover, it can be assumed that the usage of a humanoid robot enhances the sense of presence and might potentially have psychological benefits not only for the remote participants but also for their physically present colleagues.

At present, the NAO robot has its limitations but we suppose that in the nearest perspective there will be accessible humanoid robots capable to achieve all the mentioned goals.

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