Holographic Telepresence

Knowledge Unit

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1. What is Holographic Telepresence?

Holographic telepresence (HT) allows to bring together people who are miles apart. As a hologram is a 3D image, this technique generates a three-dimensional replica in one or several remote places in real-time. What makes HT superior to 2D telepresence is that it portrays humans in their true shape, "trust, loyalty and bonding" can flourish.[1] As HT can provide an immersive, more personal and engaging experience of communication, there is great potential for HT to replace current modes of communication in different areas.[2] Whether or not a two-way communication is possible will depend on the technical realization on both ends.[3][4]

1.2 What does one-way or two-way-mode mean in this context?

While in one-way mode, only one person will appear as a hologram and the other person might e.g. appear on a common 2D screen. However, if it goes in two directions, both participants will see a hologram of each other.

1.3 What distinguishes Holographic Telepresence from other Extended Reality technologies?

HT, like Augmented Reality (AR) and Virtual Reality (VR), is included in the range of technologies of Extended Reality (XR). XR technologies recreate physical worlds or simulate reality through digital environments and enable a "surrounding feeling". HT's unique selling point is that no glasses, headset or smartphone are needed to capture virtual animation with the eye; it is visible to the unaided eye.[5][6][7][8]

1.4 Where does the term "hologram" come from?

The term hologram is a combination of the two Greek words "holos" and "gramma". "Holos" means "whole" and "gramma" means "message", resulting in the meaning of creating a "complete picture".[9]

1.5 What types of holograms exist?

Analogue traditional holograms (reflection holograms, transmission holograms or hybrid forms) are produced e.g. by two laser beams lighting an object. Whereas **computer-generated holography (CGH)** is a hybrid form of the traditional types that uses computer software to calculate holograms. These holograms of the object or person are created digitally from several sources, such as depth-sensing cameras.[10][11]

1.6 How is a 3D hologram being projected?

A hologram is either a 3D image or giving the impression of being 3D.[12] Thus, 3D holograms can be projected in various forms, with several types representing optical illusions, e.g. by specific reflection systems or illumination. A "true" 3D hologram is defined to be a complete 3D volumetric image in mid-air.[13]

The term of *volumetric video capturing* is being used to describe the creation of 360° videos that capture light from all possible directions with several sensors and bring video production from flat 2D videos to videos showing a volume. All actions of a scene are recorded as 3D volumes, consisting of voxels. A voxel is a three-dimensional pixel. For this light-immersive video capturing from multiple perspectives and angles, a great amount of data has to be processed.[14] When producing a volumetric video e.g. of somebody in a studio, he/she can then watch the 3D video from every angle on mobile devices, VR or AR glasses as well as 3D displays.[15] "Viewers can change their view of a performance at any time, or actually move around the video, in mixed reality experiences."[16]

3D-Content for XR applications can be produced via:

- 360-degree video: An "inside-out capture of panoramic video acquisition is used, where the user stands at the centre of the view and can look around, left & right, or up & down. The interaction has three degrees of freedom (3-DoF), namely the three Euler angles."[17]

- 3D from real scenes: For this approach the outside-in capture is used, where the user can freely move through the scene and look around, allowing six degrees of freedom (6-DoF), including the three Euler angles and three directions of translation. In this category, several sensors are considered, such as (1) multi-view cameras including light-field cameras, depth, and range sensors, RGB-D cameras, and (2) complex multi-view volumetric capture systems."[18] [19] [20]

- 3-degrees of freedom (3DoF) + head motion parallax (3-DoF+): "An intermediate category is labelled as 3-DoF+. It is similar to 360-degree video with 3-DoF, but it additionally supports head motion parallax. Here too, the observer stands at the centre of the scene, but he/she can move his/her head, allowing him/her to look slightly to the sides and behind near objects. The benefit of 3-DoF+ is an advanced and more natural viewing experience, especially in case of stereoscopic 3D video panoramas."[21]

1.7   What is Spatial Audio?

In addition to the visual aspect of Holographic Telepresence, audio technology can contribute to an immersive experience. "The science and art of Spatial Audio is concerned with the capture, production, transmission, and reproduction of an immersive sound experience."[22]

1.8   Where does technology stand when it comes to realizing HT?

In order to produce a high quality hologram, a large amount of data is needed. Data transmission (through the Internet) and processing (limited computer power) have proven to be limiting factors.

The technical developments of the last years make it easier for HT to be available. On the one hand, the production of 3D image and video material is becoming more accessible and of higher quality due to the continuous development of sensors. On the other hand, the expansion of 5G technologies enables the transmission of large amounts of data. In addition, more and more end devices are being equipped with the function of reproducing 3D animations and holographic displays are becoming more affordable.[23] [24] [25] [26]

> "Still, an evolving technology, Holographic Telepresence is slowly but steadily entering mainstream communication systems. […] By partnering with top telecom carriers like Cisco, BT, Vodafone, Telepresence through holographic imaging is poised to become the most preferred communication system of the future." resumed by Information Technology company Winimy AI.[27]

> "Nothing is missing. All the ingredients are here. Now we need to make the cake." Scott O'Brien, Founder of the volumetric video company Humense issued.[28]

Should we allow HT to be developed without any ethical concerns?

Security and privacy issues are very present when it comes to technological developments and are very important for applications of immersive technologies. In order to build real safe systems regarding immersive technologies, ethical aspects need to be issued as well. To establish a mutual understanding of ethical concerns between stakeholders, standards are an important tool that should also address communication, measurement, commerce and manufacturing in order to help avoiding big failures, as stated by the Cyber-XR Coalition in 2020.[29]

Anna Valeri, Researcher and XR Design Ethicist from France is currently working on her research project of designing the Ethical Framework for XR (EF4XR), where she is reflecting the different relations that compile human existence and digitalized society and platform hosts.[30]

2.   Applications on the Market

2.9   Which HT solutions are available that enable two-way communication?

Holographic displays are one possibility to display holograms. Several companies are specialized in this field. One of the companies that aims to make these technologies available to the mass market is "**Looking Glass Factory**" (Brooklyn, US). Prices start at $249, for the 7.9" Looking Glass Portrait (this product is still in the crowdfunding phase). The Looking Glass 15.6" is already available and costs **$3,000**. Using the Looking Glass light field display in combination with a depth camera, participants can see and interact with each other without the need for glasses or headsets and realize holographic telepresence for a cheap price. It is planned to make the 3D teleconferencing system available starting at less than **$1,400**.[31]
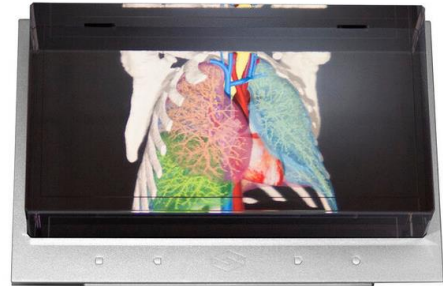

Figure 1: Looking Glass 15.6" (Source: Holoxica, Looking Glass Factory)

The company **DVE** (California, US) is the "world leader in holographic telepresence", as stated on their website. The **DVE Holo Podium** including a 65" screen is **$ 48,000** or **$ 38,000** for Universities. This product includes a high-end video conference system and is suited for one person. It creates the illusion that a live person is standing behind the podium and the screen is not visible to the "audience". The person visible as a hologram can also see the person(s) in front of the podium via a monitor and interact with them. "This product has been sold for 12 years already, especially to Universities, and works very well" says Jeffrey Machtig, Co-founder of DVE. **The DVE Immersion room** is a system that enables 16 people in total to take part in a holographic meeting, with 8 people per side and second tiers on every side. The system starts at **$ 1,2 million**.[32]

Figure 2: DVE Holo Podium (top) and DVE Immersion Room (Source: DVE telepresence)

The single-passenger holoportation machine **HOLOPORTL** by **PORTL** Inc. (California, US) allows people to "beam in" from remote locations for human sized, life-like interactive communication in real-time. The person being beamed will have the unique ability to see, hear, and fully interact with their global audiences in 4K holographic resolution. Prices for the machines start at **$ 60,000**. "Everyone with a camera and a white background can send a hologram to the PORTL."[33] [34] [35]

Figure 3: Holoportl (Source: Portl Inc.)

Figure 4: The Holopod System (Source: ARHT Media)

HoloPod™ Display by **ARHT Media** (CAN) "delivers the real-life, two-way communication with no noticeable latency of our event HoloPresence™ display but in a plug and play cabinet that wheels into place and is operational in minutes. Combined with the ARHT Engine™ software, it enables the speaker or specialist to connect with their audience, creating a true sense of presence, whether the audience is one person, one hundred or a thousand." ARHT Media promotes, that with this system the impression is created, that a person is physically present in a room, and not just in a box.[36]

The **Q-Room** is a holographic, immersive service desk, which was developed by **Quintetto** (IT) and the National Research Institute of Italy. It is an innovative tele-relationship system based on digital holography, which received funding by the EU Framework Programme for Research and Innovation "**Horizon2020**". With Q-Room a real human interaction from distance is being made possible: not a recording, nor a pre-set series of questions or answers and neither a "cold" and impersonal video screen, or a dark, somber glass box.[37] [38] [39] The aim was to enable services for people in remote locations without the need of physical presence e.g. of bank counsellors, stated by Ivano Canteri, Senior Vice President in Marketing & Sales at Quintetto. Specialized services such as digital signing and exchanging money can also be added to the system. Depending on architectural and technical execution, the system costs between **€ 40,000** and **€ 50,000**.

Figure 6: Q-Room (Source: Azer Kurt/ArtStation)

Figure 5: Q-Room (Source. Quintetto)

2.10   Which 3D content production solutions are available?

"**Azure Kinect DK** by **Microsoft** is a cutting-edge spatial computing developer kit with sophisticated computer vision and speech models, advanced AI sensors, and a range of powerful SDKs that can be connected to Azure cognitive services. Using Azure Kinect, manufacturing, retail, healthcare, and media enterprises are leveraging spatial data and context to enhance operational safety, increase performance, improve outcomes, and revolutionize the customer experience." The Azure Kinect DK consists of 1-MP depth sensor with wide and narrow field-of-view (FOV) options, 7 microphone array for far-field speech and sound capture, 12-MP RGB video camera for an additional color stream that's aligned to the depth stream, accelerometer and gyroscope (IMU) for sensor orientation and spatial tracking and external sync pins to easily synchronize sensor streams from multiple Kinect devices, it costs **$399**.[40] [41]

Figure 7: Microsoft Azure Kinect DK (Source: Microsoft)

Infineon's **REAL3™ time-of-flight (ToF) image sensors** enable electronic devices to acquire a real 3D image of the scene in front of the device. The surroundings, objects and people are transformed into the digital space in real time. Algorithms use that data to measure distances and sizes, to track motions and to convert the shape of objects into 3D models. The products are designed to be integrated into the smallest 3D ToF camera modules, accurately measuring depth in the short and longer range at the lowest power consumption. Infineon's products have been used e.g. in several

Figure 8: 3D image by Infineon's REAL 3™ fime-*of-flight image sensors*

smartphones as well as AR Headsets, smart home devices, industrial cameras and cars. Infineon developed its family of REAL3™ 3D ToF sensors together with pmdtechnologies, a ToF-focused company. So far, only a few companies have managed to bring suitable solutions to the market because broad system competence and deep understanding of the technology is required. Infineon and pmdtechnologies see themselves in a pioneering technology role.
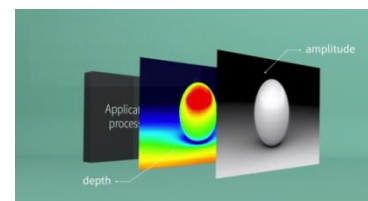
Latest Apple products such as the **Apple iPhone 12 Pro** or the **Apple iPad Pro 2020** are LiDAR-enabled, which enables 3D scanning, mixed reality and more. LiDAR (Light Detection and Ranging) is used to determine distance by measuring how long it takes light to reach an object and reflect back. The custom-designed LiDAR Scanner uses direct time of flight to measure reflected light from up to five meters away, both indoors and out. It works at the photon level, operates at nanosecond speeds, and opens up tremendous possibilities for augmented reality and beyond." The Apple iPad Pro is equipped with the A12Z Bionic chip and 8-core graphics processor which enables fluid and fast performance such as 3D design and augmented reality.[42] [43] The Apple iPhone 12 Pro is available for a price starting at **€ 1,149**, the Apple iPad Pro 2020 is available for a price starting at **€ 879**. Video Impression: https://twitter.com/albn/status/1321514603432521728

The **Volumetric Capturing (VolCap)** system by [**CERTH and VRtogether**](#) is a toolset designed to orchestrate the capturing, streaming and recording of data acquired from a multi-sensor infrastructure that captures volumetric videos. It is a multi-sensor (volumetric) capturing system that is built to use low-cost commodity hardware, quick to setup by offering automatic and scalable sensor connectivity. It is easy to deploy due to a markerless and facile volumetric calibration and documented across its multiple aspects, deployment, setup, hardware, etc. It

Figure 9: Volumetric Capture by VolCap (Source: Volumetric Capturing)

has been used in various research and development activities including live tele-presence in Augmented VR or Mixed/Augmented Reality settings and was funded by the European Commission as part of the H2020 program.

HOLOSYS by [**4DViews**](#) (FR) is the only fully-packaged, high quality volumetric capture system available on the market. HOLOSYS (Latest Version 3.5) offers a fully-packaged volumetric video capture system to equip a professional creative studio for the production of volumetric video sequences. People are being filmed and a 360° virtual 3D object is generated, which can be used for virtual, augmented and mixed reality applications with real performances. Unparalleled visual and emotional realism are increasing users' immersion and natural awareness of the experience. It includes a 4DViews' hardware for performance

Figure 10: HOLOSYS by 4DViews (Source: 4DViews)

caption and 4DViews' volumetric system software to generate high quality volumetric video sequences. The package includes the HOLOSYS system software, software license (product-life), 8 volumetric capture pods, 1 control unit, 1 processing system, 1 calibration wand, 1 targeting rod, 1 data storage unit, 1 ceiling lighting set and support, on-site installation and on-site training. On our request, the company stated, that the system starts at a price of **€ 350,000** up to **€ 500,000**.

2.11 In which fields is HT being applied?

Holographic Telepresence has already been applied in educational environments and business meetings, product presentations, gaming as well as teleconferencing and events, e.g. for business, political, royal and celebrity purposes as well as in the health sector. For example ARHT Media used the HoloPod Display to deliver quality healthcare specialists for mental and physical therapy to locations that don't provide certain medical expertise locally. The NH Hotel Group installed holographic technology in several of their hotels to enable holographic telepresence and presentations for their customers. [44] [45] [46] [47]

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