### 7.2.2. HUD, AR HMD AND EYEWEAR SYSTEMS

In the early 2020s, affordable and high-quality waveguide technology has already allowed the emergence of AR glasses, though the first products still bear distortion from the background because of the thickness of the lenses. Nevertheless, the possibility of providing a full view of the surrounding real world without sophisticated, high-quality, and computationally costly image-rendering techniques is a great advantage compared with HMD systems. Indeed, to reproduce the full view of the surrounding world, using camera-based images, colocalized with the observers' viewing directions, with an HMD allowing IPD adjustment (necessary for correct distance perception)[388] is a computationally costly task. In addition, AR glasses are less bulky, more natural, and easier to wear; therefore, their use is also more apt for large-scale deployment, with traditional HMDs still not being sufficiently adopted by everyday consumers.

AR glasses may use XR multi-chip architecture technologies used for HMDs, such as Qualcomm's Snapdragon XR2 platform (see also Sections 2.2, 2.3 and 4.4). This platform integrates many necessary technologies for the correct integration of a virtual space, such as dedicated hardware for motion tracking, localization, and image recognition, as well as processing capabilities for camera and sensor data, thus enabling eye tracking. This unique platform is used by many HMDs, such as Meta Quest, HoloLens, Magic Leap, and Varjo, as well as eyewear products such as Google Glass, Lenovo ThinkReality, and Vuzix. Furthermore, lenses for AR glasses are available from several waveguide optics technology providers, such as Optivent, Lumus, or Digilens. They provide 50° FOV high-resolution viewing boxes using micro-display projectors and waveguide lenses with 75% transparency or more and up to thousands of cd/m² luminosity, allowing their use inside or outside according to the designed version (see also Section 2.4 and 4.4).

Waveguide technology dynamics bring large AR glasses and eyewear product development in the coming years and decades, restricting the use of HMDs to specific professional environments. In the future digital AR world, everyone will wear AR glasses, which would also allow aging users' vision to be adapted to the desired viewing distances, equipped with high-performance AR-HMDs when required for specific design tasks or improved immersion when watching 3D movies. The user of this future *augmented digital* world could also share AR or VR spaces with others, due to the various 3D screens everywhere, using light-field 3D rendering, replacing the by-then-obsolete stereoscopic technology.

One issue that arises when using augmented reality headsets and goggles is how users can control them, as the view of the surrounding world is filtered by the augmented reality optical or video see-through AR display system, restricting the user's access to control devices (see also Chapter 4, Section 4.2 Perception of distance and motion). Gaze, gesture and voice input may be used, as proposed by Microsoft[389] (see also Chapter 1, Section 1.1 What is 3D) or by Apple[390], nevertheless it may be perceived as somewhat counterintuitive and difficult to handle.[391] Ongoing research is therefore carried out, booth at industrial and academic laboratories, such as Meta's CTRL-

[388] Inappropriate IPD, which influences the perceived binocular vergence, may cause significant distance perception errors. See, for example: Lee, Sangyoon et al., "Effects of optical combiner and IPD change for convergence on near-field depth perception in an optical see-through HMD." IEEE Transactions on Visualization and Computer Graphics 22.5 (2015): 1540–1554.

[389] https://learn.microsoft.com/en-us/dynamics365/mixed-reality/guides/operator-gestures-hl2.

[390] Apple Vision Pro 'Gaze and Pinch' gesture combo is perfect for AR & VR - Apple Vision Pro Discussions on AppleInsider Forums

[391] To look at a virtual object and tap with your fingers may be seen as unnatural. Indeed, it may limit the free exploration of the surrounding world, as done usually, without attention and control of gaze, to activate a specific task.

Labs, working on new types of control devices, including neural input devices, such as wristbands using electromyography (EMG).[392]

Moreover, waveguide technology should also be used in onboard vehicle HUD systems, becoming a distinct part of the user's everyday 3D visualization space. Car makers will keep this solution to provide drivers with essential information, particularly when taking back control from self-driving mode. Add-on automotive HUD providers may also propose AR glasses and/or connectivity devices to interface and synchronize the eyewear to vehicle data. The advantage of using AR glasses is the possibility of keeping the already used and adapted glasses, the connectivity devices enabling user data to be recorded, which can be reused when necessary.[393] On the other hand, integrated onboard HUDs are already interfaced and adjusted with optimal observation characteristics, which allows their use by all vehicle users, including occasional drivers. They are offered at a higher price as an option when purchasing a vehicle.

The use of 3D rooms, screens, or dedicated 3D display systems will also undoubtedly be used for telepresence systems, allowing lifelike 3D communication between users. The subjects will be scanned in real time with their 3D models visible at a distance, in *3D vision*, taking their head movements into account.[394] All user data, recording and measuring user behavior, health, and motion, will ensure enhanced user safety and comfort, but at the expense of sharing all personal data as well as the control of information, available for shopping, displacing, or interacting with others, with the system providers and appropriate authorities (e.g., health organizations and government bodies). User safety and comfort require data sharing; thus, the next decades will witness the development of data management regulation at the local, federal, and international levels.

The audiovisual and kinesthetic *likeness* of the rendered and displayed virtual world will probably also be highly enhanced. Studies have shown that subjects may experience an illusion where they feel the touch of a viewed object on their *virtual twin* hand at the place of their hidden, real hand, as if the virtual hand had sensed the touch.[395] Other experiences have demonstrated the dominance of visual input in a multisensorial environment and the "illusion" of force feedback, induced by sole visual cues.[396] Future technologies will no doubt propose high-level likeness in producing the view of virtual environments and human interactions, handing control of human perception and social life to artificial control systems.

## 7.3. THE GAFAM, AUTONOMOUS VEHICLES, AND AR

There is an increasing debate about the role of telecommunication infrastructure providers and users in investing in the ever-growing bandwidth of connectivity as well as who should pay for it. Today, the application providers, many based in Silicon Valley and using close to 50% of the available bandwidth, do not pay for any of the

[392] https://www.cnet.com/tech/computing/behind-the-doors-of-metas-top-secret-reality-labs/. Meta has acquired CTRL-Labs in 2019 for close to $1 billion, see: https://venturebeat.com/ai/facebook-acquires-ctrl-labs-to-advance-its-brain-machine-interface-efforts/.

[393] The user may even seamlessly switch his or her sunglasses from near to far vision and vice-versa through adaptive pixelated liquid crystal lens technology. See: https://www.deepoptics.com/

[394] Lawrence, Jason, et al. "Project Starline: A high-fidelity telepresence system." ACM Trans. Graph., Vol. 40, No. 6, (2021): 242-1-13. For an updated and less cumbersome version, see also: https://www.theverge.com/2022/10/13/23400870/google-project-starline-3d-chat-booth-impressions

[395] Botvinick, Matthew, and Jonathan Cohen. "Rubber hands 'feel' touch that eyes see." Nature 391.6669 (1998): 756–756.

[396] Lécuyer, Anatole et al. "Pseudo-haptic feedback: Can isometric input devices simulate force feedback?" In: Proceedings of the IEEE Virtual Reality (2000): 83–90.

necessary huge investment costs and make huge benefits due to the free use of communication services.[397] Both the US and EU are introducing new rules for the use and payment of telecommunications services. Though it is only the beginning of this new approach to managing telecommunication services used for several decades, it will bring major modifications to the ways in which business is done. However, it seems clear that in the new innovation investment, GAFAM and more generally Silicon Valley may again play a crucial role in view of the necessary investments and the already initiated computer semiconductor and engineering developments.

Fortunately, European and US regulation bodies are progressively proposing the necessary rules to be applied by the largest online platforms about how to handle user data.[398] In addition, the European Commission has issued recommendations in July 2023 to ensure that the use of Web4.0, including metaverse, 3D environments, AI, brain computer interfaces (BCI), and internet of things, a market of €800 billion (€16.6 billion for the automotive industry), in the EU is fair and respectful of citizens.[399]

Nevertheless, the largest online platform companies, including GAFAM and BATX (Baidu, Alibaba, Tencent and Xiaomi) are handling huge mass of user data (see also Section 7.2) and with the fast emergence of web4.0 deploying overwhelming technologies, impacting strongly users' knowledge, behavior and shopping practices.[400]

## 7.4. Toward the Future

Stanislas Lem, writer of science fiction as well as essays on futurology and social advances, including cybernetics and VR, depicted the consequences of incoming technological progress and their effects on the human sociocultural evolution in *Return from the Stars*.[401] In this novel, after a couple of years of space travel, which takes some 127 years on Earth due to time dilation, the novel's hero returns from *Fomalhaut* to find humans unable to take any risks or initiative. They have even lost their ability for self-assertion. They are *betrized*, sort of vaccinated against violence, living in a violence-free society, with automated cars available for all, equipped with a safety system that makes any collision or traffic accident impossible.

In 1960 (the original version of the novel was published in 1961 in Poland), Lem forecast the generalization of autonomous vehicles, in the same way that he anticipated the advent of virtual characters for theatre performance (who are still to arrive, though virtual 3D figures are progressively taking over). His analysis of the social impact

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397 https://techmonitor.ai/technology/networks/big-tech-accounts-for-over-half-of-global-internet-traffic, viGoogle sets Internet record with 25 percent of U.S. traffic - CNET, https://www.gearrice.com/update/sfr-wants-netflix-and-gafam-to-pay-for-their-high-bandwidth-consumption/.

398 According to the European Digital Market Act (DMA), gatekeeper (large online) platforms are required to allow their business users to conclude contracts with their customers outside the gatekeeper's platform and may no longer track end users outside of the gatekeepers' core platform service without effective consent having been granted, see: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/digital-markets-act-ensuring-fair-and-open-digital-markets_en. The European Digital Services Act maintains that companies that host other's data are not liable for the content unless they actually know it is illegal. It provides stricter control than the Section 230 of the Communications Decency Act (CDA) in the United States, which gives broad immunities to intermediaries, see: https://itif.org/publications/2021/02/22/how-other-countries-have-dealt-intermediary-liability/. In addition, DSA introduces obligations on disclosing to regulators how the platforms' algorithms work, as well as transparency on how decisions to remove content are taken, see: https://www.euractiv.com/section/platforms/news/eu-launches-research-centre-on-algorithmic-transparency/.

399 https://digital-strategy.ec.europa.eu/en/library/virtual-worlds-and-web-40-factsheet.

400 Google is proposing its Genesis AI tool for news generation, in competition with human written journalism, see: https://www.theverge.com/2023/7/19/23801282/google-ai-journalism-genesis-generative-news.

401 New York: Harcourt Brace Jovanovich, 1980.

of autonomous vehicles, or the social and technological changes at the origins of the advent of autonomous vehicles – with humans now being increasingly ready to hand over the control of a car[402] – questioned the price of a supposedly safer life for a society deeply influenced by risk aversion.

Similarly, entire swathes of life, through technology ranging from connected refrigerators to health monitoring watches, can be delegated to AI to achieve a safer and easier life. The future will reveal whether these technologies and their deployment will provide not only a safer but also a much healthier life, better adapted to our environment, or whether humans may be stuck in their set, like in the movie WALL-E,[403] without much capacity for self-motion. This is the very same self-motion publicized for the adoption of autonomous vehicles by new-wave Silicon Walley companies.

The impacts of several recent technological evolutions have already been studied in developed countries, including the relationship between the deployment of television, obesity, weight-related chronic diseases,[404] and cognition decline.[405] It is too early to draw any link between the future deployment of autonomous vehicles and any undesirable effect of their everyday use, as Lem depicted. Nevertheless, a study has shown that the use of GPS-based navigation systems severely impairs people's spatial navigation knowledge and skills, and that the more users engage with a GPS-like map, the worse spatial representation they acquire.[406] However, the integration of humans' displacement, just as their other activities, must respect not only the technological ecosystem but also the planet's biological ecosystem, which is tightly linked to humans and their activities.

The author of this book humbly recognizes, as a personal testimony, that from using automotive navigation systems for more than 20 years, though very useful in everyday life, he now experiences great difficulty in navigating without them. This is even sometimes the case when navigating on already well-known roads, as soon as there are several forks and roundabouts, often changing orientation. Nevertheless, the huge road safety benefits of the use GPS maps, such as the use of an intelligent speed adaptation (ISA) system, which will be progressively introduced on European roads[407] and is already considered to bring enhanced road safety,[408] will make their deployment irreversible.

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[402] https://data.consilium.europa.eu/doc/document/PE-82-2019-INIT/en/pdf.

[403] https://fr.wikipedia.org/wiki/WALL-E.

[404] https://www.hsph.harvard.edu/obesity-prevention-source/obesity-causes/television-and-sedentary-behavior-and-obesity/.

[405] Fancourt, Daisy, and Andrew Steptoe. "Television viewing and cognitive decline in older age: Findings from the English Longitudinal Study of Ageing." Scientific Reports 9.1 (2019): 1–8.

[406] Hejtmánek, Lukáš, et al. "Spatial knowledge impairment after GPS guided navigation: Eye-tracking study in a virtual town." International Journal of Human–Computer Studies 116 (2018): 15–24.

[407] https://ec.europa.eu/transport/road_safety/specialist/knowledge/speed/new_technologies_new_opportunities/intelligent_speed_adaptation_isa_en

[408] Oei, Hway-Liem, and P. H. Polak. "Intelligent speed adaptation (ISA) and road safety." IATSS Research 26.2 (2002): 45–51. The EU's updated General Safety Regulations II requires manufacturers to equip their vehicles with advanced safety features, planned for July 2022, becoming mandatory for all vehicles to be registered, covering ISA, Lane keeping assistance (LKA), event data recorder (EDR) - an automotive black box (by analogy with the name of flight recorders), and a driver monitoring system (DMS), for drowsiness and distraction monitoring, among many other safety requirements. https://www.tuvsud.com/en/resource-centre/stories/revision-of-the-eu-general-safety-regulation. EDR may also play an important role in crash analysis of self-driving vehicles. Indeed, though when in self-driving the car manufacturer is responsible for all failures, as soon as it is disactivated the driver takes back responsibility of the vehicle. Legal disputes are expected when in L3 self-driving mode the driver does not follow car makers' instructions (e.g., hand on or eyes on) and a road accident is generated.

Only time will tell whether an overly broad use of AI will also improve humanity's ability to adapt to the planet and cope with future challenges. Indeed, humans could become overly reliant on the tools provided by AI, and as a result use less human intelligence. While AI has enormous potential, particularly in terms of problem solving and decision making, it should not be forgotten that the human brain has a potential that cannot even be fathomed, with $10^{11}$ neurons and $10^{14}$ synapses for connections between neurons, giving a virtually infinite combination of connected neurons.