Virtual Reality – "Just to be cool is not enough"
An intermediate report of the FIG Working Group 6.3

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SUMMARY

Immersive technologies such as Augmented Reality (AR) or Virtual Reality (VR) have become an important topic in surveying engineering. These technologies can be used where conventional 2D screens reach their visualization limits, and the availability of high-resolution 3D data is already partially challenging conventional approaches. However, the application of immersive technologies still lags behind their actual technical possibilities.

FIG has set up Working Group 6.3 to bring together surveyors with immersive technology expertise to share knowledge but also to support the community. This paper is an introduction to the working group's work and action plan.

An initial consensus in the discussions on the state of the art, was the distinction between the technical state of the devices (e.g. head-mounted displays) and the state of the applications in which they are used. Although great progress has been made in hardware development, and sophisticated devices are available on the consumer market, geodetic applications are mostly limited to demonstration and training. Moreover, the acceptance of the various immersive technologies varies greatly. For example, AR is already part of commercial products, while VR is still lacking widespread commercial adoption. Therefore, a focus of the working group is on VR technology and its promotion as a sophisticated tool for various geodetic applications.

This is to be achieved through workshops, sample applications and code. An online survey has been set up to ask the surveying industry about their experiences with immersive technologies in order to gain a better understanding of the state of the art. The preliminary results are shared in this paper.

1. INTRODUCTION

The availability of high-resolution 3D data has shaped the surveying profession since the commercial breakthrough of laser scanners in the early 2000s. Thanks to advances in computing power and algorithms topics such as 3D information modelling, artificial intelligence, and the Internet of Things are present in the everyday lives of surveyors.

However, the digitisation process not only opened new business opportunities, but the way we interact with datasets is also influenced by these new technologies. For a long time, 2D screens were sufficient to visualise points and vectors in CAD environments, but the processing of complex 3D data is revealing the limits of conventional 2D devices. Modern planning models from architects or civil engineers slowly replace 2D plans and provide detailed 3D geometry from the outside (Figure 1a) but also from the inside (Figure 1b).

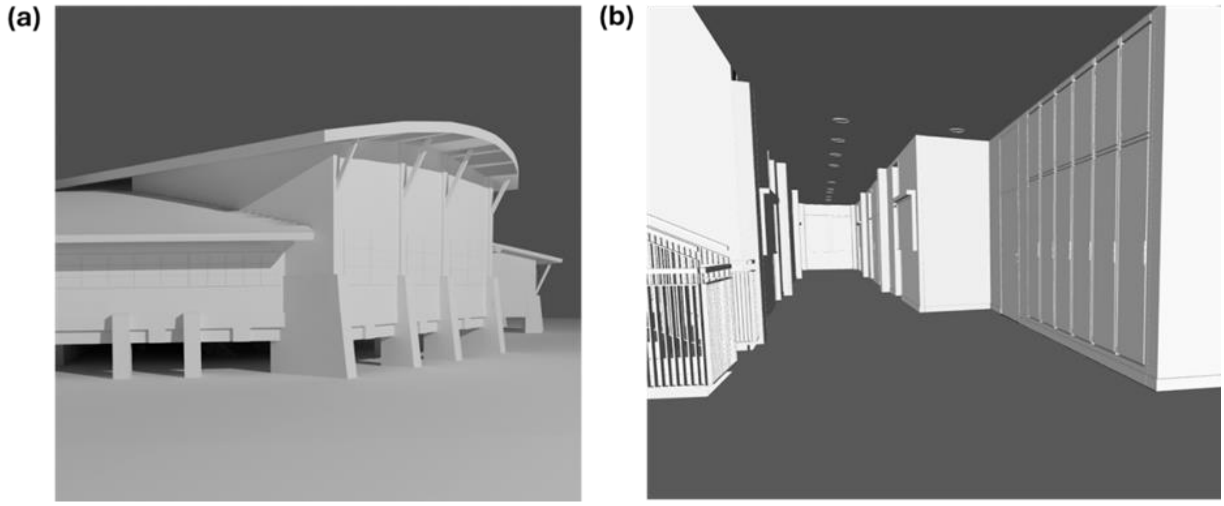

Figure 1: Revit model of the Engineering Laboratories, California State Polytechnic University, Pomona (a) and interior of the Graz University of technology

Therefore, immersive technologies such as Augmented Reality (AR), Virtual Reality (VR), and mixed reality (MR) provide new possibilities for Human-Computer-Interfaces to keep up with these new 3D data environments. Also, due to Building Information Modelling (BIM) (Sacks et. al.,2011) and the Internet of Things (IoT) (Milenkovic, 2020) immersive technologies have become a much-discussed topic in the surveying industry.

In 2023, the FIG launched an international working group on the use of immersive technologies in engineering geodesy to provide a better platform for discussions on this topic and to assess the state of the art. The aim of the working group is to bring together surveying professionals with experience in immersive technologies and digital twins to share experiences and exchange their knowledge on AR/VR/MR with the community.

This paper is an interim report of the working group, briefly summarises the discussions to date and gives an overview of the direction in which the working group is moving. It also presents the working group's planned actions and calls for further participation. Interested parties are cordially invited to take part in the online survey provided or to contact the authors directly.

2. IMMERSIVE TECHNOLOGIES: BRIEF OVERVIEW

Augmented Reality (AR)

AR refers to a technology that superimposes digital content—such as images, text, and sounds—onto the real-world environment, creating an enhanced user experience that blends physical and virtual elements (Azuma, 1997). AR systems typically rely on devices such as smartphones, tablets, or head-mounted displays (HMDs) to deliver this interactive experience (Billinghurst et al., 2015).

These systems use a combination of sensors, cameras, and software to analyse the environment, detect surfaces, and position digital objects in a spatially coherent manner. The core functionality of AR involves three main components: real-time interactivity, spatial alignment, and integration of digital content with the physical world. Unlike Virtual Reality (VR), which immerses users in a completely synthetic environment, AR maintains a direct connection to the real world, enhancing, rather than replacing, the user's perception of their surroundings (Milgram & Kishino, 1994).

AR has found applications across diverse fields, including education, healthcare, retail, manufacturing, and entertainment (Peddie, 2017). In healthcare, for instance, AR assists in surgical planning and visualization by overlaying anatomical structures on a patient's body. In industrial settings, AR is used for assembly instructions and maintenance tasks, providing workers with real-time, context-sensitive guidance (Wang et al., 2016). The technology also plays a significant role in education and training, where it facilitates interactive and immersive learning experiences.

Virtual Reality (VR)

VR is a technology that immerses users in a fully synthetic, computer-generated environment, simulating sensory experiences that replicate or enhance real-world or imaginary settings (Burdea and Coiffet, 2003). Unlike Augmented Reality (AR), which overlays digital content onto the physical world, VR replaces the user's environment entirely, creating an interactive and immersive virtual space (Sherman & Craig, 2003).

These days, VR experiences are typically delivered through head-mounted displays (HMDs), often accompanied by accessories such as motion controllers, haptic devices, and spatial audio systems, to enhance interactivity and realism. The core principles of VR include immersion, interaction, and presence. Immersion refers to the sensation of being enveloped in a virtual environment, while interaction enables users to manipulate and engage with virtual objects or settings. Presence is the psychological effect of feeling physically situated within the virtual world, achieved through high-fidelity visuals, realistic audio, and responsive system behaviour. VR applications span a wide range of domains, including entertainment, education, healthcare, training, and research. In entertainment, VR is widely used in gaming and cinematic experiences, offering users unparalleled levels of engagement. In education and training, VR creates realistic simulations for skill development, such as flight simulators for pilots or surgical training for medical professionals. Healthcare applications include exposure therapy for treating phobias, pain management, and rehabilitation exercises in a controlled virtual setting.

An applications for the training of surveying students with VR was created by Bolkas et. al. (2022) and can be seen in Figure 2. Furthermore, such virtual environments can be also used in geodesy in the design processes and feasibility studies of future surveying campaigns, as proposed by Bauer and Lienhart (2022).

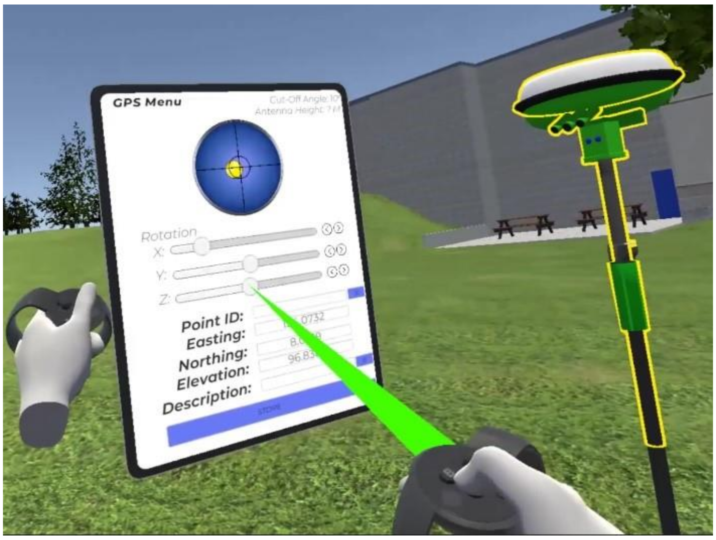

Figure 2: Virtual Reality training for surveying students (Bolkas et al., 2024)

Mixed Reality (MR)

MR refers to a spectrum of immersive technologies that seamlessly blend the physical and virtual worlds, enabling real and digital objects to interact in real-time within a shared environment (Milgram & Kishino, 1994). Positioned between AR and VR on the reality-virtuality continuum, MR creates experiences where virtual content is not only overlaid onto the physical world but also anchored and integrated in ways that allow dynamic interaction between the two realms (Speicher et al., 2019). MR typically employs advanced devices such as head-mounted displays (HMDs) like the Microsoft HoloLens or Magic Leap, alongside sophisticated software for environmental understanding. Key components of MR include spatial mapping, context-aware interaction, and adaptive integration of virtual and real-world elements (Schmalstieg & Hollerer, 2016). Spatial mapping allows MR systems to understand and model the physical environment, enabling precise placement and interaction of virtual objects. Unlike AR, where digital overlays are often static, MR content responds to the physical surroundings and user actions, creating a dynamic and immersive experience. This interaction enhances the user's sense of realism and engagement.

Applications of MR span a wide range of industries. In healthcare, MR is used for advanced surgical planning and intraoperative guidance by projecting 3D anatomical models that align with a patient’s body. In education and training, MR provides learners with hands-on experiences, such as virtual laboratory experiments or immersive fieldwork simulations. Industrial applications include collaborative design, maintenance, and remote assistance, where MR facilitates real-time visualization and interaction with digital prototypes or digital twins, as in the construction sector for example to compare plans to the actual built situation. Entertainment and gaming also leverage MR to deliver experiences that blend physical and digital gameplay elements seamlessly (Peddie, 2017). In Figure 4 the wide range of MR applications within a geodetic context can be seen. From “VR applications” with simple digitiser tools (Figure 3a) or sophisticated simulations with realistic haptic devices (Figure 3c) up to interactive overlays of a sandbox (Figure 3b).

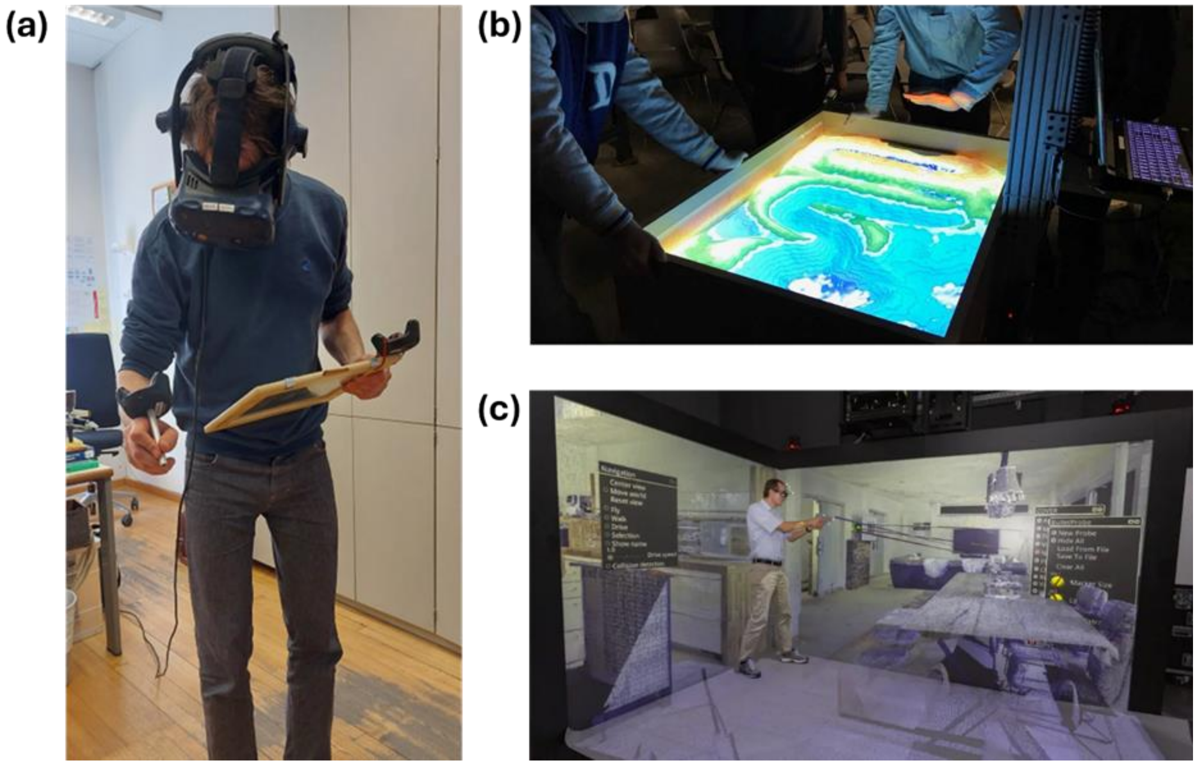

Figure 3: (a) Digitalisation application by TU Graz, (b) Augmented Reality Sandbox with students by the California State Polytechnic University, Pomona and (c) CAVE application for forensic experts by the LKA BW, Stuttgart.

360° images and videos

360° images and videos also play a role in the development of immersive technologies like AR, VR, and MR. These media formats provide panoramic, spherical content that allows users to explore a scene in all directions (3 degrees of freedom (DoF): only rotations) and are an inexpensive way to get started. With a 360° (3D) camera you can quickly generate videos and images that you can later play back on your HMD device, creating a heightened sense of immersion and presence.

However, there are challenges to consider: High-quality 360° content requires substantial storage and processing power, especially for VR and MR applications and for AR and MR, integrating 360° media must align seamlessly with real-world elements to avoid disrupting user engagement. But more importantly, unlike fully modelled 3D environments, 360° media is generally pre-rendered and lacks dynamic interactivity. This means that the 3D content can not be explored freely (6 DoF) and the interactions are limited to the pre-set viewpoints.

Therefore, 360° media views have to be categorised somewhere between 3D cinema and real AR/VR/MR applications from a surveying perspective. They are immersive, but they lack the 3D modelling component, which is the essential part for the seamless integration into digital twin applications. Therefore, this category will be addressed separately from AR/VR/MR within the scope of this paper and the further work of the working group.

3. STATE OF THE ART IN ENGINEERING SURVEYING

The interdisciplinary character of the surveying profession and the high degree of digitalisation in geodetic workflows are the perfect starting point for the implementation and usage of immersive technologies. Hence, it is not surprising that many geodetic institutions and companies have experimented with it over the last decade. For instance, Lütjens et. al. (2019), Traxler er. al. (2019) and Levin et. al. (2020) among many others.

Although the literature suggests a wide acceptance of AR/VR/MR in the scientific field, different levels of development are evident in the best practice of the surveying industry.

For example, 360° images and videos are already well established in everyday life. These can be created with almost any modern camera or laser scanner on-the-fly or in post-processing from a series of images. Corresponding viewers are often offered free of charge or are integrated into commercial software. Nowadays, they are a very popular medium for sharing 3D views online or offline with others (for instance: Leica TrueView (Leica Geosystems, 2025) or the Matterport software (Matterport, 2025)).

AR is almost as accepted as 360° videos and it is already being used for many commercial applications. One of the earliest applications of AR in surveying was the on-board software of modern total stations. The display of measurement points as an overlay on the on-board screen is now a standard function. But applications such as Trimble Site Vision (Trimble, 2025b) or Leapfrog AR also use mobile devices (smartphones and tablets) as dynamic 3D interfaces. Their ability to render designed features (e.g., building), collected points and surfaces, and underground utilities has proved to be very useful and an important field tool for surveyors. With software environments like Trimble Connect (Trimble, 2025a) a solution for the AR-field visualisation of common data environments (CDE) is available for everyone.

VR seems to be the least accepted and utilised technology in the surveying industry. Although it is well established and widely used in the scientific community with numerous data visualisation and interaction applications, only few commercial geodetic VR solutions can be found. Instrument manufacturers have integrated VR viewers in Leica True View or in Faro Scene, but beyond the visualisation of measurement data, VR is not fully leveraged as a real working tool.

This limited integration of VR technology for technical applications (beyond basic visualisation) was the starting point for discussions within the working group. The most important questions are: What prevents people from using VR in everyday life and how can the barriers be removed?

In these endeavours the work of the FIG working group partially overlaps with a working group of the ISPRS (Technical Commission V, Working Group 1) and is in close exchange. The ISPRS working group deals with the application of immersive technologies in geodetic education as a new teaching and training method. The results of that working group are summarised in Bolkas et. al. (2024).

3. THE ISSUES OF VIRTUAL REALITY

The public opinion often claims that VR cannot be used on a large scale due to comfort issues and motion sickness (Biswas et al., 2024). It is also widely believed that the high cost of development and software maintenance makes it unreasonable to use.

However, these arguments are only partially true, as a brief look at the gaming sector shows. In contrast to geodesy, VR is an established method in video games. Huge gaming blockbusters such as The Elder Scrolls 5[1] or Fallout 4[2] have been released with VR controls. These games prove that complex controls and input systems can be handled with VR and that (although motion sickness is still an issue) most viewers can stay in virtual environments for hours without major problems.

Furthermore, is should be noted that game shops (Steam, Play Store or Meta Store) are full of relatively cheap applications from arcade-shooters (see Figure 4b) to space walks (Figure 4a), and that VR integration has become part of the standard control variants in game design. The arguments against VR, regarding motion sickness and complexity can be invalidated. So, from a technical perspective, VR should have achieved a major breakthrough in the field of video games. However, like geodesy, it has fallen short of expectations.

In the gaming sector, however, the reason for this is more obvious. Like many innovative approaches, it has suffered from excessive commercialisation. Well-made examples like Half-Life: Alyx[3] or the virtual tour of the ISS, (Game: Mission to the ISS[4], see Figure 4a), proof that games with well-thought concept are very positively received by the audience. However, for the huge majority of available games VR was seen as a cash-cow and games with poor quality (bugs and poor concepts) have earned the distrust of the community.

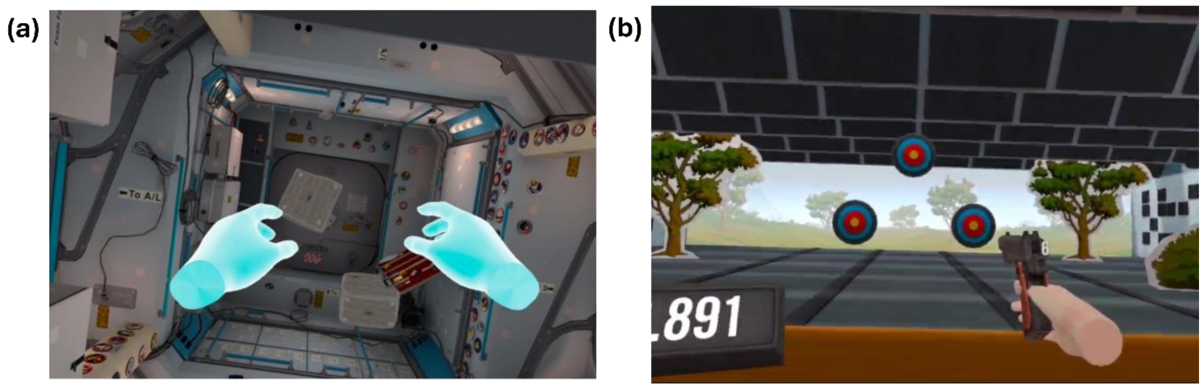

Figure 4: (a) Screenshot from Mission to ISS and (b) a screenshot Zombieland[5]

This aligns in a way with the situation of VR in geodesy. Although bugs and poor graphic is not much of a big deal here, the right methodological implementation is a key element to the success of the software. Therefore, it became apparent in the working group that the absence of ideal use-case of VR usage in geodesy is the biggest issue, and that many people have often simply no idea what to do with it. Although the opinions in the discussions vary from collaborative working to decision making processes, it was agreed that the simple visualisation of 3D point clouds (or static 360° videos) are an easy product but neglect most of the advantages and capabilities of VR.

VR in geodesy suffers from a lack of real integration into workflows, interoperability with software products and data exchange platforms. VR allows (or should be designed to allow) users to intuitively access and work with 3D models without the need to learn complex

[1] Link to Steam: https://store.steampowered.com/app/611670/The_Elder_Scrolls_V_Skyrim_VR/
[2] Link to Steam: https://store.steampowered.com/app/611660/Fallout_4_VR/
[3] Link to Steam: https://store.steampowered.com/app/546560/HalfLife_Alyx/
[4] Link to the Meta store: https://www.meta.com/de-de/experiences/mission-iss/2094303753986147/
[5] Link to the Meta store: https://www.meta.com/de-de/experiences/zombieland-headshot-fever/2792447070854325/

keyboard shortcuts and menu structures. The focus is on the content, not the software tool. It should make complex 3D datasets accessible to a wider and more diverse audience without the need for trained 3D perception (which is required during plan reading).

VR offers many advantages for digital twins, for example enabling different stakeholders to meet virtually on the construction site for planning, discussions, and presentations. The stakeholders can for instance place and change virtual objects, which is then automatically reflected in a database that holds the (as-built/as-is) BIM model (Blut et al., 2024).

The working group therefore believes that it is important to differentiate between the technical components of VR and the content that is viewed with it, when discussing the status of VR, as this is where major differences in the level of development become apparent. For instance, in the example of collaborative platforms of BIM processes, it is the operational digital twin that is more science-fiction rather than the VR integration. Because for viewing the content in VR, the content has to exist in the first place. For VR meetings, Meta provides ready-made tools for virtual conferences and the integration of 3D surveying models in this setup should be only a small technical task when it is demanded by the community.

4. PROFESSIONAL INSIGHTS

To incorporate not only the opinions of the working group members, but to also get community feedback an online survey was created and will be maintained until the end of the working group in 2026[6].

The survey consists of interesting questions related to immersive technology use and adoption in the surveying profession. A total of 30 individuals had completed the survey by the end of 2024. 17 of the respondents being from Academia, 5 from government agencies, and 8 from the industry. Respondents are from N. America, Africa, Europe, and Asia. The survey results reveal that 63% have used immersive technologies and 38% have not. 60% of the respondents indicated that they have used such technologies for work and another 40% that they have used it for both work and entertainment. None of the respondents said that they have used these technologies for entertainment only. When asked what technologies they have used, the responses reveal that those engaged with immersive technologies will tend to use more than one technology. MR received the lowest score of 67% and 360 content received the highest score of 94%. VR is second with 89% and AR third with 72%. This also shows that no particular technology is preferred, but once started people tend to familiarise themselves with the whole spectrum of immersive technologies,

[6] Link to the online survey: https://pennstate.qualtrics.com/jfe/form/SV_8ijIWYN8kX2lCQe

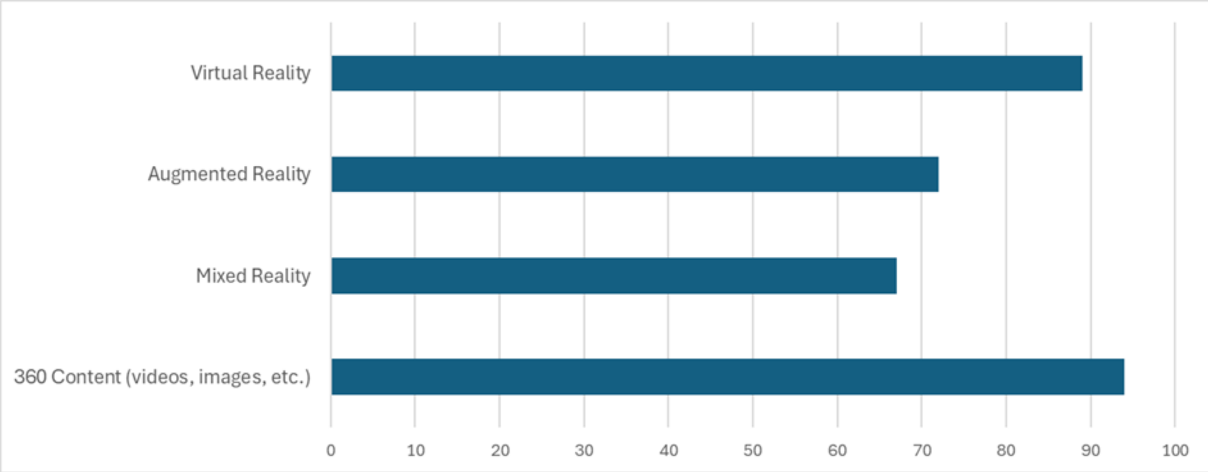

Figure 5. What immersive technologies have you used?

On the other hand, asking the respondents why they have not used any of the immersive technologies, their responses revealed that the biggest barriers are the lack of commercial software or lack of development ability, cost, and IT support. This indicates a lack of maturity in the industry to develop the necessary commercial software that will spark widespread adoption.

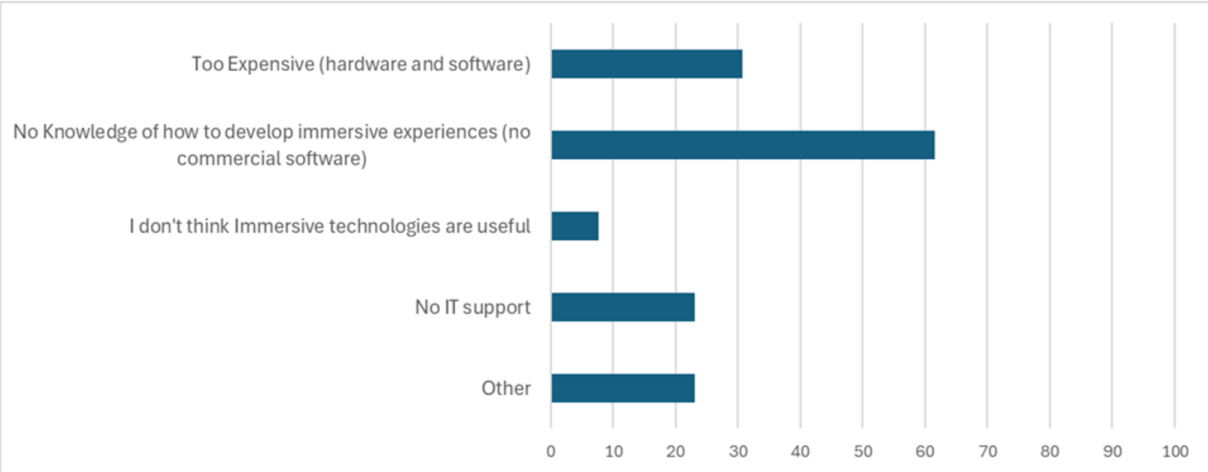

Figure 6: Why have you not used any immersive technologies so far?

The majority of the respondents (89%) indicated that they have used immersive technologies to simply view 3D content. Another 61% indicated that they use immersive technology for education and training. 50% of the participants said that they use immersive technologies for data interaction and analysis, and another 28% for field data collection. These results reveal that beyond simply viewing point clouds and 3D models, few professionals have used immersive technologies for more advanced tasks such as field data collection and data analysis. This result can be related to the previous conclusion regarding the lack of commercially available software that will offer more advanced processing tasks and allow for widespread adoption in the industry. Nevertheless, and despite the barriers, most of the participants believe that the immersive technologies are going to become an important component of the geospatial industry (77% agreed, 23% said maybe, and 0% disagreed with this statement).

Similarly, the majority of the participants believe that immersive technologies will become an important component of geospatial education (82% agreed, 18% said maybe, and 0% disagreed with this statement). Furthermore, the participants believe that the immersive technologies are going to become an important component of the geospatial industry (77% said yes, 23% said maybe, and 0% said no).

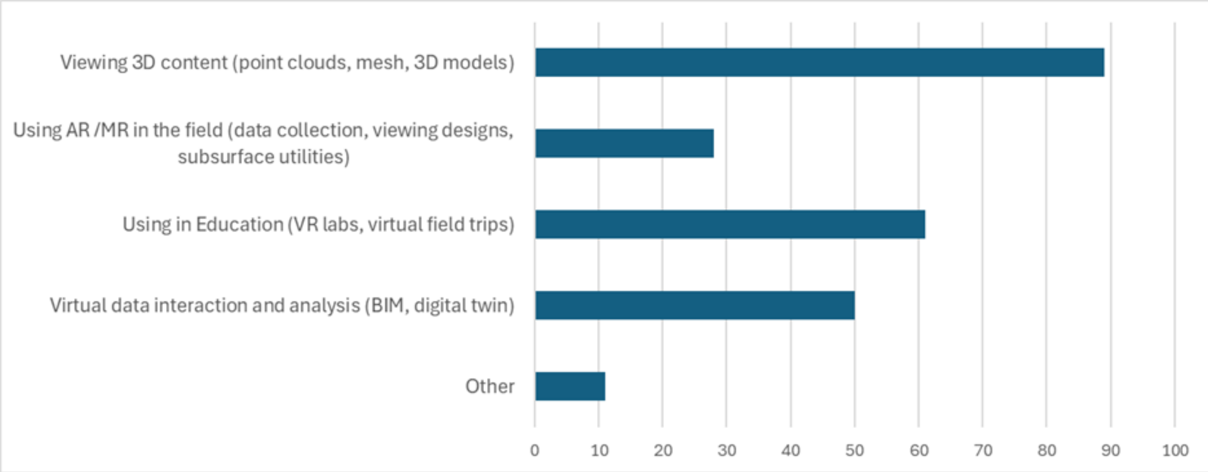

Figure 7: How does your employer / company / university use immersive technologies?

5. DEMOCRATISATION OF VIRTUAL REALITY

It can be concluded that the application of VR technology on a larger scale faces two major problems: On the one hand the lack of integration into existing workflows and therefore little commercial interest by major companies, and on the other hand certain provisions by the geodetic community to do the development work on their own, as shown by the online survey.

The working group is well situated to address these provisions. Here, the long-term-goal is, once the community starts using VR headsets on their own, more and more workflows will be adapted for VR usage. This creates business cases, which then will be picked up by major companies which have the resources to create even better applications. But the initial start, and the workflows (e.g. the content) must come from the community itself. If the development of VR workflows (content) is solely driven by major companies, geodesy might face the same problems as the gaming industry, where the content doesn't match the demands and the quality standards.

Therefore, it is the main idea of the working group to promote VR as a technology, not only for scientific usage, but as a technology for everyone. Just like simple 3D viewers on the PC, which are available on any device nowadays, VR can be an everyday tool. Due to affordable consumer headsets and user-friendly game engines, this is a very realistic scenario (from a technical perspective).

It is time for geodesy to recognise that VR has been around for quite some time. The first prototypes were developed in the 1970s for immersive data visualisation (Sutherland, 1968), and since then the devices have maintained their futuristic image, which they have retained to this day due to their frequent appearance in science fiction films and television series.

With the emergence of VR systems on the mass-market, this futuristic image should have been slowly dismantled. The first Oculus Rift prototype in 2013 was the start of ready-to-use VR systems for the gaming market. Afterwards in 2016, also other companies entered the market.

Sony has adapted a VR system for the PlayStation 4 and HTC launched the first Vive System. At least by then, mature and ready to use systems were available to the great audience. This development is also reflected by the Gartner hype cycle (Fenn, 1995) which placed the VR technology on "the slope of enlightenment" by then and removed it in 2018 from the list of emerging technologies and therefore should be commonly labelled as "mature".

Therefore, a major aim of the working group is to support and motivate people to start using VR on their own and start getting in touch with the technology.

6. ACTION PLAN OF THE WORKING GROUP

Part of the contributions completed by the working group include the collaborative creation and dissemination of the online survey discussed in Section 4. The survey will be maintained and promoted until the scheduled end of the working group in 2026. The outcome of the survey will be published as a part of the working group's closing report and in the form of a published paper.

Another major aim is to support and motivate people to create their own immersive applications. Therefore, free webinars and workshops are planned to introduce game engines and guide users through the first steps of VR software development. The first webinar on Unity application development is scheduled for the beginning of 2025, as seen in Figure 9. The webinars are a cooperation with the FIG Young Surveyor Network to reach a wider audience via their social media presence.

Figure 8: LinkedIn advertisement of the Unity webinar

Furthermore, a sample application for the Meta Quest VR platform will be developed. The application and associated source code will be made freely available. This source code will also be made available as part of the working group's final report.

The working group has made significant steps towards supporting the geospatial community by providing free and ready-to-use 3D models of surveying instruments. These 3D objects are often hardly available, because instrument distributors are reluctant to share their designs and schematics. This requires reverse engineering by the users or the purchase of commissioned custom models. Given their lack of popularity, these models not only tend to be expensive but can be of substandard quality.

The aim of the working group is to collect models that have been created by geodetic experts and to make them available for free download on the online platform Sketchfab[7]. Any reader who wants to share 3D models and contribute to this work is invited to get in touch with the authors.

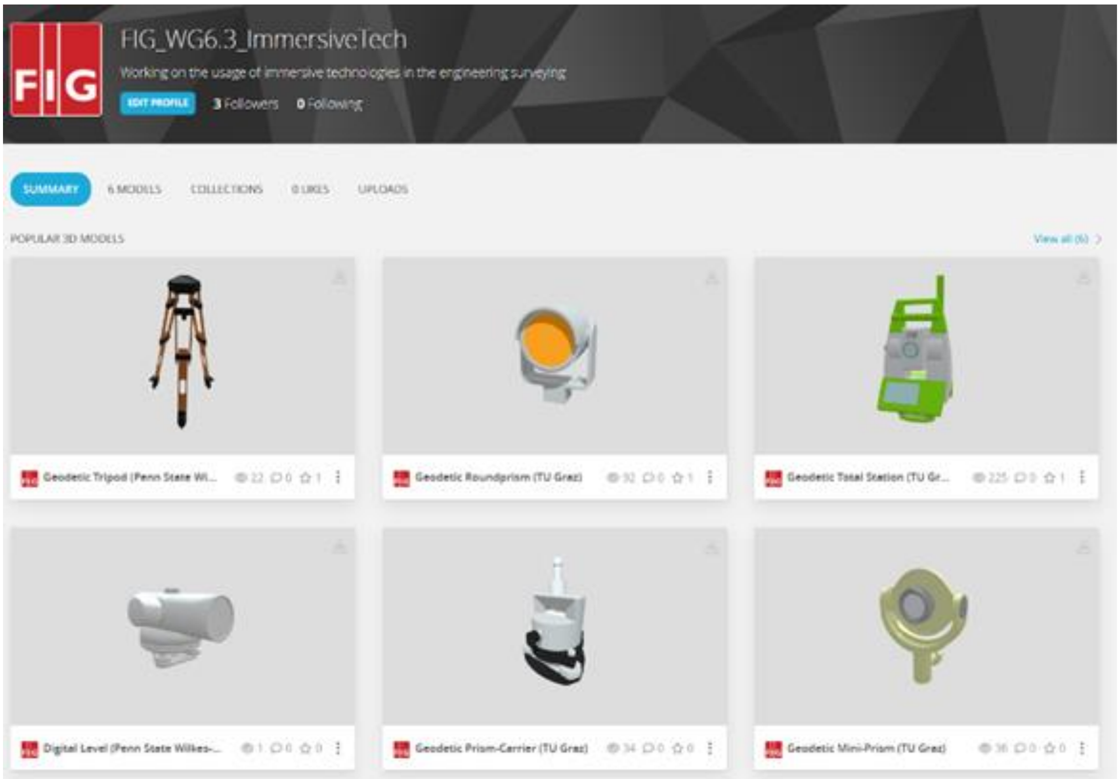

Figure 9: Screenshot from the object catalogue on Sketchfab

The purpose of this publication is not only to inform readers of ongoing work, but to invite those that may be interested to contribute to the above-mentioned efforts. Lastly, we kindly request that you participate in the online survey, even if you have no experience with VR, your opinion is highly appreciated.

[7] Link to the FIG Sketchfab page: https://sketchfab.com/FIG_WG6.3_ImmersiveTech

7. SUMMARY

Virtual Reality has become a popular topic amongst Geodesy and Geospatial professionals. In BIM immersive technologies play a pivotal role for displaying and interacting with the spatially accurate representations of real-world structures and objects. Therefore, the FIG has created a working group on the topic of immersive technologies in engineering geodesy. The current working group focuses on the promotion of VR technology for surveying applications. The discussions of the working group and the evaluation of an online survey indicate that the biggest problem for the adoption of VR on a larger scale is the lack of integration into existing workflows and knowledge barriers by geodetic experts.

VR should not be seen as science-fiction anymore, but as a mature working tool that is ready to be used. Therefore, it is necessary to foster a broader community of users who are motivated to engage with VR technology. This will be achieved by improving the knowledge and experience of the community through publications, webinars, and freely available coding examples and 3D model assets. This paper serves as an intermediate report on ongoing and future working group activities. A final summary of working group contributions will be released in 2026.

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