Immersive VR Experience of Redeveloped Post-industrial Sites: The Example of “Zeche Holland” in Bochum-Wattenscheid

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Abstract

Modern hardware and software innovations in the field of virtual reality (VR), such as VR headsets and accessible game engines, allow cartographers to create 3D environments which can be experienced from the ego perspective in real time and with a simulated illusion of physical presence (immersion) in the virtual representation. The new immersive experience of these virtual environments requires new ideas on how to present and orchestrate geographical information for the benefit of planning applications. This paper intends to present examples how VR-based 3D environments use can be enriched (based on the game engine Unreal Engine 4) to support the district development of a restructured post-industrial area. A VR model of a representative former industrial area in the German Ruhr district which was revitalized and part of a large urban transformation programme (IBA Emscher Park), serves an example. Today, the area of “Zeche Holland” in Bochum-Wattenscheid is characterized by a mix of residential and commercial uses. The area is used as a leisure route for locals and tourists, with an old winding tower as an important urban landmark in its centre. VR techniques allow to transport additional spatial information which cannot be experienced when visiting the real physical area. This paper addresses the potential of immersive VR environments representing a multifaceted and redeveloped area for planning and related usage scenarios. It shows how peculiarities of game engine-based VR can help to extend the immersive (3D) experience of geographic information.

Keywords Virtual reality · 3D cartography · Multimedia cartography · Urban transformation · Navigation · Open data · Constructivism

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Immersive Erfahrung umstrukturierter post-industrieller Standorte in VR: Das Beispiel der „Zeche Holland“ in Bochum-Wattenscheid

Zusammenfassung

Moderne Hardware- und Software-Innovationen im Bereich der Virtuellen Realität (VR), wie bspw. VR-Headsets und verfügbare Spiele-Engines, ermöglichen Kartographinnen und Kartographen 3D-Umgebungen zu erstellen, die aus der Ego-Perspektive in Echtzeit mit einer simulierten Illusion einer physischen Präsenz (Immersion) in der virtuellen Repräsentation erfahren werden können. Die neue immersive Erfahrung dieser virtuellen Umgebungen erfordert neue Ideen, wie geographische Informationen präsentiert und inszeniert werden können, um bspw. Planungsanwendungen zu unterstützen. Dieser Artikel enthält Beispiele, wie VR-gestützte 3D-Umgebungen (basierend auf der Unreal Engine 4) angereichert werden können, um als Werkzeug für die (Weiter-)Entwicklung eines umstrukturierten post-industriellen Areals zu dienen. Zu Veranschaulichungszwecken wurde ein VR-Modell eines repräsentativen ehemaligen Industrieareals im Ruhrgebiet erzeugt, das innerhalb eines umfangreichen urbanen Transformationsprogramm (IBA Emscher Park) revitalisiert wurde. Heute zeichnet sich das Gebiet der „Zeche Holland“ in Bochum-Wattenscheid durch eine Mischung von Nutzungsformen (v.a. Wohnen und Gewerbe) aus. Das Areal enthält zu dem eine Freizeitroute für Ortsansässige und Touristen sowie einen erhaltenen Förderturm, der als urbane Landmarke dient. VR-Technologien erlauben die Einbindung und Vermittlung zusätzlicher raumbezogener Informationen, die bei einem Besuch des realen Areals nicht erfahren werden können. Dieser Aufsatz adressiert Potenziale immersiver VR-Modelle von vielseitigen und umstrukturierten Arealen für die Planung und verwandte Anwendungsszenarien. Er zeigt zudem, wie Besonderheiten von Game-Engine-basierter VR-Visualisierung helfen kann, um die immersive (3D-)Erfahrung von geographischen Informationen zu erweitern.

1 Introduction

The technical opportunities to create detailed 3D environments for a real-time and immersive use make it possible to highlight geospatial details in multifaceted areas (see also Çöltekin et al. 2019). In redeveloped post-industrial spaces, such as former industrial areas of the Ruhr district, cartographers can highlight projects at different scales and address different user groups in a connected VR environment. In immersive virtual environments, both spatial and timely restrictions can be overcome. Users can experience changes of positions in space and respective perspectives which they cannot experience in the real environment. Addressing specific user groups of the restructured area, additional (geo) data sets can also be linked (as animations) to spatial objects in the VR model. Moreover, future planning projects can also be simulated at different scales. Objects of the past with a high historical value can also become part of the VR-based application and transported through different approaches. This extended virtual experience of an area may shape new impressions and ideas, which may have an impact on landscape perception and planning.

Urban planning projects often integrate historic heritage sites into the concepts of re-development of urban quarters. Planners as well as architects suggest ways to combine traditional building fabric with modern—and extremely differing—usage demands. The consequences for urban planning triggered by the preservation of identity-creating landmarks can be seen, amongst other aspects, in the consideration of the height of neighbouring buildings and in the creation of visual axes towards (and perspectives on) the historical

object. Moreover, this also includes the consideration of the local terrain and the consequences of shadow cast on residential buildings and ecologically sensitive sites. For simulating different scenarios and analysing the effects of reality-like scaled perspectives on people's perception of a planned area, more sophisticated visualization tools are required that can meet such complex requirements.

The main objective of this paper is to introduce and discuss the potential of modern approaches of immersive VR that support the presentation and communication of spatial information to different interest groups of multifunctional post-industrial areas. The case study deals with the example of “Zeche Holland”, a redeveloped and multifunctional post-industrial area in Bochum-Wattenscheid (Ruhr district). The location is known as a small-scale site which is representative for structural change and post-industrial urban transformation in the Ruhr district. New usages and constructions are brought together (in a compact area), with relicts of the industrial past that are part of the regional history people identify with. The valorisation of old industrial objects can be interpreted as an expression of increasing appreciation and identification with the industrial past and heritage (Jenal 2019a; Kühne 2007, 2018b; Slotta 1988). The mix of ‘old and new’ generates interest of different stakeholder groups, such as planners, entrepreneurs, potential residents and cultural tourists. Modern VR also evokes interest for constructivist landscape research, as well as the potential of constructivist landscape research for the theoretical framing of VR research, which is also addressed in this paper. Modern methods and techniques of immersive experience in virtual reality may bring additional value to communicate spatial and geographical information to these interest groups.

After a brief introduction to the historical development of “Zeche Holland” in Sect. 2, the third chapter is dedicated to a short presentation of relevant and transferrable workflow steps that shows how to derive a 3D terrain model from official open surveying data in a VR-compatible game engine (Unreal Engine 4). This technical step is necessary to create a reliable and accurate 3D base (layer) for the site. This chapter is followed by a presentation of different examples of how the immersive experience of VR environments could bring benefits for the communication of spatial information. These benefits refer to different user groups in the multifunctional sites. A fifth chapter introduces interactive visual navigation aids which are established approaches in video and computer gaming, but hardly explored in VR-based 3D cartography. These approaches may improve the usability and communication of spatial information in future VR-based projects. Before a summary is given in Sect. 7, additional potentials of immersive VR environments for constructivist approaches of landscape research are briefly discussed in Sect. 6.

2 “Zeche Holland”: From Hard Coal Mining Area to a Multifunctional Diverse and Ecological Urban Space

In December 2018, the last piece of hard coal was mined in the Ruhr district, Germany. It was a symbolic act that marked the end of an industrial era in a region which had been economically, socially, and culturally shaped by hard coal mining for about two centuries. The reduction and removal of industrial capacities in the Ruhr district had however been a longer process that already begun during the coal and steel crisis in the late 1950s (Wood 2003, pp. 119–122). In the following decades, the coal production steadily decreased. As a result, production sites ceased operations (Huske 1998).

The decline in coal mining left over large areas in the Ruhr district which required new concepts of urban usages and functions. The largest programme for the far-reaching management of structural change in the Ruhr district was IBA Emscher Park. This programme was focused on a paradigm shift removing the ‘rust belt’ and establishing a revitalized and greener metropolitan region (Otto 2019; Kilper 1999, pp. 129–130; Müller and Carr 2009). Many post-industrial brownfields were incorporated into a wide-ranging sustainable concept (cf. Reicher 2008). This fundamental project of urban transformation involved the small-scale consideration of the new potentials of the individual post-industrial sites. New multifunctional spaces were created which were made available to a broader public and which offered different and mostly small-scaled usage scenarios.

The former coal mining area associated with Zeche Holland shaped the industrial urban history of the Ruhr district cities Gelsenkirchen and Wattenscheid (incorporated into Bochum in 1975) for about 120 years. In the second foundation phase of hard coal mining in Germany’s Ruhr district, investors started to establish the shaft mines III (1873), IV (1898), V (1907) and VI (1921) which formed the Wattenscheid part of Zeche Holland. The last shaft of the mine (VI) was finally closed in 1988 (Regionalverband Ruhr 2019).

After mining was stopped in the 1980s, the post-industrial site became part of the structural change programme IBA Emscher Park. In the IBA Emscher Park programme, the area of Zeche Holland was assigned to the model project called “working in the park”. An environmentally oriented technology centre was founded as the ‘innovative core’ located in the modernized and listed office buildings. The shaft tower “Holland” (see Fig. 1) was preserved to maintain a landmark representing the industrial past (Kilper 1999, pp. 129–130). It serves as the core visual orientation point in and around the area (see also Bähr 2012, p. 352). Other

Fig. 1 A symbolic landmark reminding of the industrial past in the Ruhr district (textured 3D model)

parts of the area, including the area of an adjacent mining heap, were planned for office and residential premises (see also Regionalverband Ruhr 2018). The residential use is imbedded into a concept of ‘living for the elderly’. Residential estates were particularly designed for barrier-free living circumstances (Kilper 1999, p. 130). Large areas of the brownfield land were revitalized with green and grassed areas to make urban greening visible in the residential and commercial zones and to stress the ecological component of the project (Kilper 1999, pp. 129–130; Schaller 1991, p. 45). A route for pedestrians and cyclists was created whose course widely matched the old industrial railway track and which connected the restructured and multifunctional area to other sites of a regional green corridor. In 2015, a former parking lot area was converted into a container village serving as refugee domicile. Figure 2 indicates the present use of the redeveloped area.

These newly conceptualized urban areas are characterized by diverse facets of geospatial information, such as area divisions, building outlines, land cover and land use. This also includes three-dimensional aspects, such as relief formation, the individual shape of buildings and their facades, appearances of cultural landmarks or a bird’s eye perspective on the overall composition of the restructured landscape.

Hence, these multifunctional areas contain a lot of valuable three-dimensional information that require current forms of 3D data presentation and access. VR techniques provide new and suitable opportunities for interactively analysing and simulating 3D representations of multifunctional landscapes. To create spatially accurate 3D landscapes, VR

creators require a suitable and VR-compatible 3D base (layer). As (official) open geodata are not yet available in game engine formats, 3D reliefs have to be derived based on different geo-processing steps. An example workflow is introduced in the following.

3 From the (Open) Data Download to a 3D VR Model: a Brief Workflow Summary

Modern approaches of 3D visualization originate in methods and techniques of virtual reality (e.g., Hruby 2019; Kersten et al. 2018; Büchi et al. 2018; Lokka et al. 2018; Boulos et al. 2017). New hardware and freely available mass media software enable cartographers, game designers and professionals of related disciplines—as well as ‘VR homebrewing’ citizens—to represent small-scale areas in a highly detailed way, approaching a 3D map in a 1:1 scale. Based on VR headsets, such as HTC VIVE Pro or Oculus Rift, people can move through a VR environment in an egocentric perspective or can even become part of an animated virtual world as a simulated character (avatar). This avatar can be controlled by a game pad or adoptions of real-body movements. Such virtual reality environments are based on an immersive experience of represented 3D information. The user gets the chance to perceive the virtual environment from the ego perspective and with a real-time navigation approach—an experience he or she is used to. It is simulated that the user is physically present in a highly realistic 3D representation (see also Vetter 2019; Susi 2014).

Fig. 2 Zeche Holland today: a redeveloped post-industrial site in the Ruhr district. Aerial photograph: © AEROWEST GmbH, Thomasstraße 18-20, 44,135 Dortmund, licence provider: Regionalverband Ruhr, Essen, flight date: 14 June 2016

To visualize today's topography of the former industrial area Zeche Holland, the federal government of North Rhine-Westphalia (NRW) offers suitable data sets on the terrain. As a part of the open data initiative Open.NRW (<https://open.nrw/>—last access: 13 September 2019), digital terrain models (1 m spatial resolution) are online available in different formats, such as XYZ point data (see https://www.bezreg-koeln.nrw.de/brk_internet/geobasis/hoeihenmodelle/gelaendemodelle/index.html last access: 13 September 2019). This data can be read by default GIS software, such as QGIS (v. 3.4). At present, further processing steps based on GIS tools are necessary, as (official) terrain information have not yet been prepared and offered as downloads in a VR-compatible format. In QGIS, the point data can be converted using a rasterize tool, which leads to a new (raster) output data set based on values of height data (heightmap). This height information is represented by greyscale values in Fig. 3, ranging from 51.7 m (black) to 72.1 m (white) in this case study.

Such raster data sets (format: TIFF, data type: uint16) can be read by the source-available game engine Unreal Engine 4 (released by the US company Epic Games in 2014). *UE4* was opened, including all tools, features and the C++ source code, to the worldwide community of 3D game developers. *UE4* was made available to everyone. However, if a commercial product is created with *UE4* and launched on the market, 5% of the profits must be passed on to the Epic

Games company, but only if more than \$3000 is earned in a quarterly period (Richartz 2016, p. 3).

UE4 offers the 3D representation of the heightmaps created with QGIS. When loading in the data, the user can select a “landscape material” to texturize the terrain. Figure 4 gives an impression of an imported and simply textured (landscape material: “M_Ground_Grass”) 3D terrain model of the Zeche Holland area.

In further steps, the model can be extended by adding other topographic objects, such as vegetation, water bodies and buildings. Several freely available (and also commercial) assets, i.e., object packages developed for the use in *UE4*, are offered to design realistic virtual environments. Users may also create individual 3D objects in *UE4* or in other compatible software, such as free and open-source 3D computer graphics software toolset Blender (<https://www.blender.org/>). To achieve a high positional accuracy of represented objects and spatial relations between them, imbedded 2D maps, such as official open data raster maps, can serve as visual references (see also Edler et al. 2018a).

In addition, illumination options include a simulation of realistic lighting, such as sunlight based on “directional light”. This helps to generate specific time-of-day conditions which can be further accompanied by atmospheric details, such as “atmospheric fog” (see also Lee 2016, pp. 34–37). Moreover, the light conditions based on simulated sunlight also influence shadowing of topographic objects.

Fig. 3 GIS-based 2D raster file representing height information of today's Zeche Holland area

Fig. 4 VR compatible: a simply textured 3D terrain model in *UE4* (based on open digital terrain data)

This simulation of realistic lighting and weather conditions has an obvious impact on the user impressions of a virtual landscape. For example, it helps VR users “feel grounded” (Plowman 2019, p. 141; see also Jung and Vitzthum 2013). Moreover, VR techniques facilitate the exploration of perceived atmospheres, as they arise under different lighting conditions (see also Kazig 2019; Weber 2017). In addition, different approaches to visualizing terrains in VR projects have recently been suggested in the cartographic and geodetic community (see Lütjens et al. 2019; Lindner et al. 2018).

In this paper, the (geo)data processing workflow is one example of workflow used to establish a ‘VR compatibility’ of official open (geo)data sets, supplemented by some self-created 3D objects in *UE4*. It might emphasize the value of publically accessible (geo)data for modern 3D visualization.

In addition, it might also indicate the present and future research potential referring to technical and methodological aspects of making VR models more accessible and usable. Establishing user-friendly VR-based representations of the ‘real environment’, however, requires the generation of output models that meet the need of proper usage and application scenarios.

4 Extending the Immersive Experience in VR

In immersive virtual environments, both spatial and timely restrictions can be overcome. Users can experience changes of positions in space and respective perspectives which they cannot experience in the real environment. Thanks to the possibility of walking through a 3D landscape and experiencing it from the ego perspective, users could explore it in

much more detail in VR environments than in rather traditional geographical media with lower (spatial) resolutions, such as remotely sensed images or other static 3D images (see Google Street view). Addressing the experience of specific user groups exploring the restructured areas, additional (geo)data sets can also be linked (as animations) to spatial objects in the VR model. For example, objects of the past with a high historical value can also become part of the VR-based application and can be communicated through different approaches.

4.1 Impressions Taken From Perspectives Out of Reach

In former industrial areas, material and, at the same time, symbolic items of the past, such as the shaft tower “Holland” (see Fig. 1), are often kept. In many cases, historic built-up objects like the shaft tower “Holland” are bound to a restricted usage, due to their building condition and dangers of injuries and collapse. Virtual environments, however, can ‘break’ security restrictions as well as laws of physics—without fear of negative consequences. The cartographer (creator of the VR representation) can allow a virtual character to enter locations (in all dimensions) that cannot be legally or physically reached in the real world. This may lead to new impressions on an area and create a different assessment of multifaceted landscape (see Fig. 5). In the example area, the value of the key landmark can be extended by providing views in VR which cannot be taken in reality.

Moreover, the avatar can be placed at height positions where no material object exists (or even could exist) in the physical world. In other words, the ‘virtual ego’ of the user can be positioned basically everywhere in a virtual world.

Fig. 5 Gaining new perspectives from less accessible positions ‘forbidden spaces’: an avatar standing on the top of the dilapidated shaft tower

This allows the user to experience the virtual simulation of the real environment based on completely new perspectives. This may lead to new impressions on an area, which may influence the perception of an area and may provide new impulses for visitors and for district development at different scales.

Figures 6 and 7 give example views from a virtual height platform that do not exist in the real physical landscape. The immersive perception of the area from this ‘virtual observation deck’ provides new impressions, such as a new possible view on the technology centre and its surrounding area (Fig. 6) or on the accommodations that are involved in the ‘living for the elderly’ (see Kilper 1999, p. 130) concept of the restructured Zeche Holland area (Fig. 7). Such examples of VR-based geovisualization

could help district managers to improve the locational marketing, as they have new forms of visualization and new viewing platforms to experience specific parts of the area in real time.

4.2 Adding Geodata to Improve Locational Marketing of Housing and Commercial Spaces

In addition to the possibilities of providing entirely new viewing perspectives from above, ‘VR cartographers’ can also add information that are called up interactively. Such animations can be used at different scales. To link detailed additional information to specific and detailed (3D) objects, VR cartographers can use the ‘terrestrial level’ of an immersive VR environment. The terrestrial

Fig. 6 Experiencing the technology centre and its surrounding area from a new egocentric viewpoint

Fig. 7 Experiencing the residential estates and their surrounding area from a new viewpoint

use of an immersive VR application can be described as a ‘three-dimensional walk-through GIS’, where specific semantic information (identities) are bound to topological objects. When moving through the residential quarter in the VR simulation of the Zeche Holland area, additional geographical information can appear, depending on the current position of the virtual character.

An example refers to current rent index data. When the character gets close to an apartment building, a signpost appears (Fig. 8). This signpost is not an object that can be found in the real Zeche Holland area, it is part of an animation and includes textual information on the current rental fees. It is neither an object in the virtual environment that seems to disturb the user’s impression of immersion (see also Edler et al. 2018a; Jerald 2016, pp. 279–280). The

animation includes the appearance of the signpost (animation event), as soon as the virtual character crosses an invisible container object (“box collision” in *UE4*) located close to the apartment building (trigger event).

In addition to the visual animation part, a sound sequence is played. This auditory element has a clear function to communicate specific semantical information, whereas (3D) sound in this VR application is otherwise used to create an audiorealistic impression of the soundscape based on atmospheric field recordings (see also Berger and Bill 2019; Indans et al. 2019; Laakso and Sarjakoski 2010; Schafer 1977). The sound animation at this location includes a vocal message (see Sherman and Craig 2019, p. 438). A voice is telling/reading out the rental charges. The auditory dimension, which has been

Fig. 8 Interactive animations including additional information on current rental fees

Fig. 9 Interactive animations including additional geodata for advertising commercial spaces

an established part of cartographic animation since about 25 years (Krygier 1994; Brauen 2014; Edler et al. 2019), is used here to offer a dual and redundant (audiovisual) form of communication relevant geographical information. This approach is used to enable an improved barrier-free communication which specifically addresses users with vision impairments (see also Hruby 2019; Hennig et al. 2018; Siekierska and McCurdy 2008; Krygier 1994).

A similar example of an audiovisual animation contains additional information about a service company in the Zeche Holland area (fictional photography studio; see Fig. 9). Again, entering the vicinity zone with the virtual character triggers an animation (flying text and vocal narration). This suggested example of an animation in VR is a bit more detached from reality than the previous example (signpost). The flying text does not appear as a possible object known from the physical reality, whereas the signpost has a higher degree of realism. The effects of different animation techniques in VR on the information transfer and on the impression of immersion still remain open empirical questions for future research on VR-based 3D cartography.

4.3 Learning About the Past Using Integrated Educational Media

The possibilities of VR-based visualization do not only allow to simulate the present appearance of an area or possible future developments (see Sect. 4.4). VR environments can also include interactive items that are specifically focused on the historical context of the area. It is conceivable that the whole area could be shifted

back in the past so that VR projects would serve as a highly detailed and ‘walkable’ historical 3D archive (see Tschirschwitz et al. 2019; Kersten et al. 2018; Lercari 2017; Ramsey 2017).

Another way of bringing together present and past in the same immersive VR application is based on the integration of multimedia, such as educational videos (e.g., documentaries) that provide comprehensive information about how the area and the whole region was characterized and used in former industrial times. Figure 10 shows an example where a virtual video screen (a simple 3D object materialized with a “media texture”) is positioned close to the foot of the modelled shaft tower. The virtual character of the use can play a video, on the working life in the coal mines of the Ruhr district. The video (based on an mp4 file) can be activated by a press key event near the red button on the ground. From there, the user can watch the entire (audiovisual) video in an approximate full-screen presentation, without leaving the virtual space. Other examples of educational media are text and sound files, as known from earlier examples in multimedia cartography (see Edler et al. 2015; Pulsifer et al. 2007; Francis 1999), or 3D graphical objects, such as educational panels located at relevant places in the area.

4.4 Simulating Future Development and Planning Projects

Both perspectives (immersive bird’s eye view and terrestrial view) can also bring new benefits for the simulation of future changes in the area. Methods of 3D simulations

Fig. 10 Experiencing additional media while being immersed: a video on the industrial history of the area

have been integrated into some participatory approaches in landscape and urban planning (e.g., Jamei et al. 2017; Lovett et al. 2015; Dickmann and Dunker 2014; Salter et al. 2009; Lange and Hehl-Lange 2005). Advantages of an immersive VR experience of the simulated future project lie in the real-time application and the possible permanent change of perspectives and scales when evaluating (by walking through or flying over) a planning project. Real physical barriers (see Sect. 4.1) do not restrict the access. For example, users immediately can discover a VR simulated shadow impact of high-rise buildings, such as the shaft tower, on adjacent areas (see Fig. 11).

5 Moving Through VR Environments: Interactive Visual Navigation Aids to Explore VR Modelled Landscapes

Modern VR environments do not only bring benefits for an extended experience of the represented environment based on additional perspectives or bound data, they can also benefit from methods and techniques that are intended to support orientation and navigation performance. As in many other animated and interactive approaches of cartography (see for e.g., Edler and Dickmann 2017; Ahlqvist 2011; Dormann et al. 2006; Corbett and Wade 2005;

Fig. 11 A view from above on the shaft tower and its cast shadow

Greenspan 2005), VR creators can benefit a lot from video and computer gaming to build modern (3D) cartographic media. The video and computer gaming industry has developed and established several approaches that help users and, accordingly, virtual characters to solve spatial exploration and search tasks in games successfully (Edler and Dickmann 2016; Jerald 2016, pp. 342–344; Carr 2006). The immersive experience of virtual environments can benefit from different navigation aids. These aids include additional spatial references, such as mini-maps or simple signifying footprints supporting orientation in a VR environment. These aids also refer to techniques that support an efficient and directed bridging of distances, such as teleporting techniques based on pointer teleportation (including teleport arcs) and teleport stations. These navigational aids are offered as optional components in the application of the Zeche Holland VR environment.

5.1 Mini-Maps

A navigational aid used in many game genres (for e.g., racing games, hack and slay, sports games and strategy games, see Edler et al. 2018c) is the “mini-map” (Adams 2014, p. 284/515; Saunders and Novak 2013, p. 289; Jones 2014, p. 108), also “miniature map” (Cozzi 2015, p. 356; Lavieri 2015, p. 120/162). These maps can be regarded as interactive maps which represent the ‘virtual ego’ of the user as a real-time animated map symbol and provide an additional view on the environment, usually from an orthographic or oblique perspective. This additional perspective—going back to rather traditional 2D reading of animated maps—can help to find objects or routes in unfamiliar places. Figure 12

gives an example where the user gets additional information about the possible way to the main entrance of the technology centre in the Zeche Holland area.

Established variants of mini-maps have the location of the avatar in the centre while the represented environmental elements change with motion (character-oriented mini-map, see Fig. 12). This type of mini-map has the advantage to provide a view of the detailed surrounding of the character. Small-scale objects, such as trees, cars and architectural features, can be represented in the map and better used as reference items in search and exploration tasks in the VR environment.

Alternatively, the map has a fixed spatial extent while the location of the avatar is not bound to the centre of the map field. In this example (world-oriented mini-map), the animated symbol representing the avatar constantly changes its position in the map, and the map extent always includes the same (fixed) reference objects. Depending on the extent of a virtual environment (in gaming terminology: “level”), the world-oriented approach can become problematic. Some objects, especially smaller objects (specific buildings or vegetation), are not represented sufficiently in the miniature if the scale becomes too small due to a large extent. In this case, cartographers/VR creators could deactivate certain (thematically organized) object layers, such as *UE4* and provide a generalized mini-map with linear objects, such as streets, footpaths and boundaries as continuously present objects for orientation (see an example in Fig. 13). According to recommendations of game designers, mini-maps should generally not exceed 10% of the available display area, its position on the display is not standardized (Adams 2014, p. 284).

Fig. 12 Finding the main entrance of a building using a character-oriented mini-map (left)

Fig. 13 Discovering the area of Zeche Holland using a world-oriented mini-map (left)

5.2 Footprints

Another visual aid supporting a continuous navigation is a sequence of markers, such as salient and illuminated footprints on the ground. These “signifiers” give a spatial structure and can trigger user behaviour and operations (Jerald 2016, p. 279). Such visual objects (which could also be accompanied by sound elements) can be used to indicate a route to a point of interest. For example, if the user aims to find the way to an outlet store in the Zeche Holland area, footprints can be activated to support an efficient navigation to a represented outlet store within the VR application (Fig. 14). Another example can be found in the video game Black & White (2001), where light poles assist orientation

and positioning in a 3D environment experienced from the ego perspective (Nitsche 2008, pp. 212–214). Such aiding markers could support the user’s formation of cognitive representation of the area. If the user wishes to visit the outlet store in the real physical area, the shortest (most efficient) way of walking can be recalled from its VR-based encoded cognitive representation of space (see also Dickmann et al. 2017; Bestgen et al. 2017; Edler et al. 2014).

In contrast to the mini-maps which provide a different viewing perspective on space for the time of usage, the footprint markers are merged into the 3D environment. This may better constantly keep the user’s impression of immersion, as the viewing perspective is not changed for a while (see also Edler et al. 2018a).

Fig. 14 Footprints signify the way to a destination

5.3 Pointer Teleportation

A specific VR technique of locomotion and navigation is the so-called “pointer teleportation” (Linowes 2018, p. 217). Based on the current location of the character, the user can define the location where the character should be moved to next. This motion event is comparable to a simple jump that bridges spatial distances, without an animation of ‘gliding’ (see also Jerald 2016, p. 344). To better control teleportation events, a “teleport arc” (Mack and Ruud 2019, p. 220) may be drawn which indicates the teleport destination in the VR environment (see Fig. 15, see also Kersten et al. 2018, p. 189).

Fig. 15 A teleport arc indicating the end of a pointer teleportation event in *UE4*

5.4 Teleport Station

A more standardized way of teleporting a virtual character is based on teleport stations (see Fig. 16). The VR creator can define departure locations and teleport destinations. The character can enter these departure locations, such as portals, and is directly ‘beamed’ to a specific location in the VR environment. This ‘virtual shortcut’ allows a fast change of places in the virtual world—by disabling realistic human motion, at least for a short moment.

These portals have already been used in traditional video and computer games [for e.g., *The Legend of Zelda* (1986), *Super Mario Bros.* (1985) and *Diablo* (1996)]. They allow

Fig. 16 A teleport station ‘beaming’ the virtual character to the ‘forbidden’ top of the shaft tower “Holland” (Fig. 5 shows the view from the teleport destination)

the connection of two individual places, or a linkage of one environment (“level”, or “dungeon”) with an “overworld” (Stanton 2015, p. 123; Arsenault 2014, p. 477). This time-efficient approach of overbridging of spatial distance can improve a creator-controlled “environmental storytelling” within a (game) mission (Despain 2013, p. 76).

Like pointer teleportation, this overbridging of larger travelling sequences may also help to reduce VR motion sickness (Ntokos 2019, p. 205; Jerald 2016, p. 344), i.e., a usability problem that could lead to physical discomfort caused by a conflicting perception of expected self-movements. Both approaches of teleportation help planners to reach destinations in a time-efficient way. Barriers can be passed easily and quickly, and the planners can avoid dealing with content which is irrelevant for the individual task. This loss of spatial content caused by teleportation events is, however, discussed to decrease the user’s spatial orientation, as the perceived VR environment includes gaps (Bowman and Hodges 1997).

An advantage of the station-based navigational approach is to focus the user’s experience of the VR environments to specific places, which enforces (several) users get to know specific objects and events and take similar views on specific spatial phenomena. Teleporting from one location to another also omits that users experience “immersive paradoxes” (Therrien 2014, p. 455) in geographic space, such as walking down a hill without a track or climbing up a winding tower which has no continuous stairway (see Figs. 1, 10, 16).

6 Potentials of Landscape Models in Immersive VR for Landscape Research

Beyond the practical tools that VR environments provide for immersive spatial experience, the representation of restructured areas as immersive VR environments holds potential for landscape research. Landscape research sees itself confronted with a ‘triple landscape change’ (Kühne 2019): first, physical space is subject to change; second, social interpretations and evaluations of these physical arrangements are changing; third, individual interpretations and evaluations of landscape are changing. These variabilities are feedbacked: for example, the individual evaluates changes in physical spaces, but an essential basis for these evaluations is also social patterns of interpretation and evaluation (among many: Stemmer 2016; Gailing and Leibenath 2012; Greider and Garkovich 1994; Paasi 2010; Kühne 2018a). This variability poses considerable challenges to empirical landscape research: Even small changes in the weather can lead to altered evaluation results, and the same applies to minor changes in viewing perspectives (Kühne and Weber 2019; Ingold 1993). In addition—regardless of the research method chosen, whether walks, abstract questionnaires, the

evaluation of photos, etc.—disturbance variables (such as objects that distract from the intended objects of evaluation) are usually found.

However, such disturbance variables can be minimized using VR in theory-based empirical landscape research, thus, it is possible to confront study participants only with those visual and acoustic stimuli which are desired from the research perspective (Edler et al. 2018b, 2019). Such largely standardized VR environments can be used as stimuli to record spatial preferences, combined with questionnaires of quantitative and qualitative social research (see Stemmer et al. 2019; Jenal 2019b). Further 3D eye-tracking methods (based on VR-compatible eye-tracking systems) can be used to track the eye movement behaviour during the visual task of defining spatial preferences.

Further VR-based experiments could be focussed on a landscape design aspect: study participants can intervene in the design of virtual landscapes to create their ideal or dystopian landscapes. This could refer to landscape variables, such as relief, type and area of water bodies, proportion of meadows, pastures and fields, proportion of forest, type and area of settlements.

Using techniques of VR-based landscape modelling, it is also possible to record preferred weather conditions systematically, seasons or own positions in the VR terrain (e.g., on the lower, middle or upper slope). For example, not only landscape preferences or rejections and their references to sociodemographic variables (such as age and gender), educational level or milieu affiliation can be explored, but also ‘inverse landscapes’ (Kühne 2013). These are landscape states that would be possible, but would not attain individual or social relevance, or even ecosystemic implications of these ideas. Thus, for example, the biodiversity of landscape preferences can be recorded, both in relation to the individual, according to the sociodemographic variables and milieus mentioned above, but also in relation to society, as well as in an intercultural comparison. These differentiated observations could also be used for targeted education for sustainable development but could also evaluate its success.

7 Summary

This paper introduced a VR environment which represents today’s area of the former hard coal mining site Zeche Holland in Bochum-Wattenscheid, a representative site of a vivid and successful structural change in the Ruhr district. Modern possibilities of 3D visualization based on hardware and software innovation from the gaming industry, such as VR systems and game engines, have made it possible to create and experience highly realistic 3D environments in real time and with a “perceptual illusion” (Nitsche 2008, p. 203) of being fully immersed. Immersion generates the

user impression of being physically present in the virtual world, which intensifies the experience and use of this representation.

Based on the possibilities of visualization for an immersive use in modern game engines, cartographers as VR creators can offer new perspectives on geographic space, without restrictions that occur in the real physical landscapes. For example, locked areas, such as construction sites and run-down buildings in a post-industrial area, can be entered and hovering objects (viewing platforms) can be positioned in the air while the ‘law of gravity’ is repealed. The immersive experience of the area generates new impressions which could be valuable input for planning purposes (including citizen participation), landscape architecture and quantitative and qualitative landscape research. The future development of a restructured area may benefit from these 3D impressions.

Moreover, 3D virtual environments can be enriched with visual and auditory animation sequences which bind additional (semantical) geographical information to specific objects and locations. Thus, they can provide additional geographical contents in a user-oriented approach and without disrupting the feeling of immersion. The location-based activation of additional information can be customized for different groups of interests in a multifunctional area, such as professionals (e.g., architects, planners, district managers, teachers, suppliers and construction workers) and other citizens (tourists, bikers, dog owners and other strollers; see also Afrooz et al. 2019; Aichner et al. 2019; Engelmann 2018, pp. 45–51). This also refers to multimedia contents, such as video documentaries or sound recordings of the past. These media can be used to link memories of the industrial past to present or future locations, which increases the value of immersive VR models as educational media for (geography) school education and museums, where the topic of structural change and cultural heritage in old industrial areas is relevant (see also Kersten et al. 2018; Edler et al. 2015).

These enriched VR environments can be supported by new tools of user navigation and locomotion which have been adopted from video and computer gaming, such as mini-maps, signifying markers and teleporting techniques. Their effectivity, so far, is mirrored by the success of the gaming industry, as they play essential roles in many video and computer games. It still remains an open research task to measure their impact on navigational tasks in virtual environments. Moreover, the design of such features could be further investigated, such as an optimum size, position and scale of mini-maps. Established design recommendation of (multimedia) could lead to new proposals of mini-map construction.

In addition to potential of immersive virtual reality for geographical applications, this paper has also pointed to a demand for additional methodological research

considerations to increase the ‘VR readiness’ of (open) geodata. Today, accessible official geodata, such as digital terrain models of German surveying departments, are not yet ready to be imported into the widely spread game engine Unreal Engine 4. To visualize the relief, users still have to process and convert the data in GIS before the data input works successfully. If such open data were improved for an immediate use in a (source-available) game engine, the broader public could better access the public data.

The potentials of immersive VR presented in this paper refer to the methodological and application aspects of the work with geographical information in virtual environments. The example of Zeche Holland might have introduced some of the main benefits arising from an immersive experience of virtual environments. To optimize the future visualization of such virtual landscapes, researches should explicitly involve cognitive user behaviour during the fulfilment of spatial tasks (see also Clarke et al. 2019; Keil et al. 2019; Lokka and Çöltekin 2019; Hruby et al. 2019; Edler et al. 2018b). These tracked responses will likely help to derive new recommendations for an effective human-centred design of immersive VR landscapes.

It becomes obvious that technological innovations have accelerated the development in 3D cartography. They allow a 1:1 representation of the real physical world, and an immersive real-time experience of these virtual representations from the ego perspective. This requires new empirically verified design rules and theoretical fundamentals for our disciplines that could largely benefit from design proposals (including animation, interaction and navigation tools) developed and tested out by the computer and video gaming community.

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