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Research Paper

Applications of Virtual Reality in Architecture

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Abstract
Back in the early days, Architecture used to be more of manual work, with architects used to think, visualize and express through manual interfaces like pen and paper, large drafting tables with adjustable stools, and drafting tools. But, with ever-growing computer technologies and their rapid evolution, a plethora of software aids and helps architects design and visualise better. Given this context, this article tries to understand the implications and the applications of Virtual Reality in the field of architecture, urban planning and virtual heritage with possible merits and demerits.

Keywords: Virtual Reality, Augmented Reality, New Age Architecture, Technology in Architecture

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I. INTRODUCTION

In this paper, we start by describing the evolution of Virtual Reality and highlight its practical and foreseeable application. It is a part of the problem-solving method, encompassing the cognitive and intuitive framework of analysis, synthesis and evaluation. The word "Visual" has been overly used in almost every discipline, describing the work being done cognitively. Our intention is to describe the use of VR while underscoring research and educational aspects common to visualization tools.

DEFINING "VIRTUAL REALITY"

The novel "Pygmalion's Spectacles" by Stanley G. Weinbaum in 1935 coined the term "Virtual Reality" as it depicts the invention of special goggles that allow the wearer to play movies and interact. Merriam-Webster dictionary's definition of virtual reality is "an artificial world that consists of images and sounds created by a computer and that are affected by the actions of a person who is experiencing it", it has never ended there, as its definition was not just that. Having multiple definitions and interpretations, the term "Virtual Reality" is itself an oxymoron.

figure 1 Image depicting VR's "Amazing" Shock-Factor

figure 2 The Amazing Ways Honeywell Is Using Virtual..."

EVOLUTION OF VIRTUAL REALITY

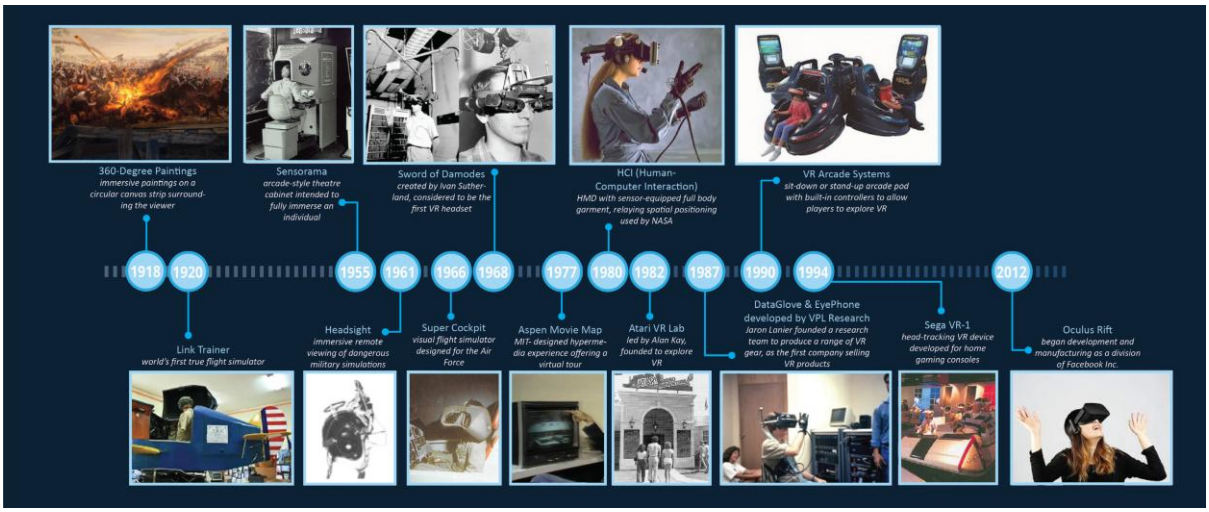

figure 3 Timeline of Historical Events Surrounding VR Creation & Implementation

Cinematographer Morton Heilig 1955 further developed this idea into a multi-sensory device called 'Sensorama', which had a three-dimensional stereoscopic display, speakers and haptic feedback through the vibration of the user's seat. Henceforth, he was called the "Father of Virtual Reality". Since then, Virtual Reality became a tangible entity in our real world. Virtual reality, having been invented as a platform for entertainment, has existed solely in the laboratory sector as a medium for research and development purposes in several fields. The breakthrough for public accessibility of VR has been since just under a decade, allowing designers, architects, visualization specialists, and gamers to find deep interests in this technology. Consumer adoption of this technology was brought forward by its native cause, the entertainment industry. Represented by blockbuster movies, books and TV shows like Ready Player One, The Matrix, Star Trek, Avatar, and Black Mirror.

DIFFERENTIATING BETWEEN VIRTUAL, AUGMENTED AND MIXED REALITIES

Extended reality (XR) is the umbrella term that encompasses the full spectrum of realities.1 These realities, namely Virtual, Augmented and Mixed, are claimed to effectively "blur the line between reality and illusion, pushing limits of our imagination and granting us access to any experience imaginable." This is accomplished differently by each of the three realities.

Virtual reality (VR) focuses primarily on two main sensory sources, viz., visual and auditory, from placing a Head Mounted Display (HMD) atop the user's head which nowadays includes headphones as well. Apart from this, haptic feedback suits and kinesthetics are also under study to be developed in the coming years. This arrangement is shut off from the physical world.

Augmented Reality (AR), its term, means to exaggerate. It enhances the real-world experience by including a digital visual input interpolate over the real surrounding using a camera device.

Despite their similar designs, virtual reality and augmented reality accomplish two very different things in two very different ways. VR simulates and allows a user to experience by replacing reality while AR adds information to reality on top of what is already seen.

Mixed Reality (MR) takes the real world and integrates computer-generated content to interact with the view of the real world. It carries the ability to take fully-generated digital environments and connect them to real-world objects, making it the only technology able to combine analogue and digital realities.

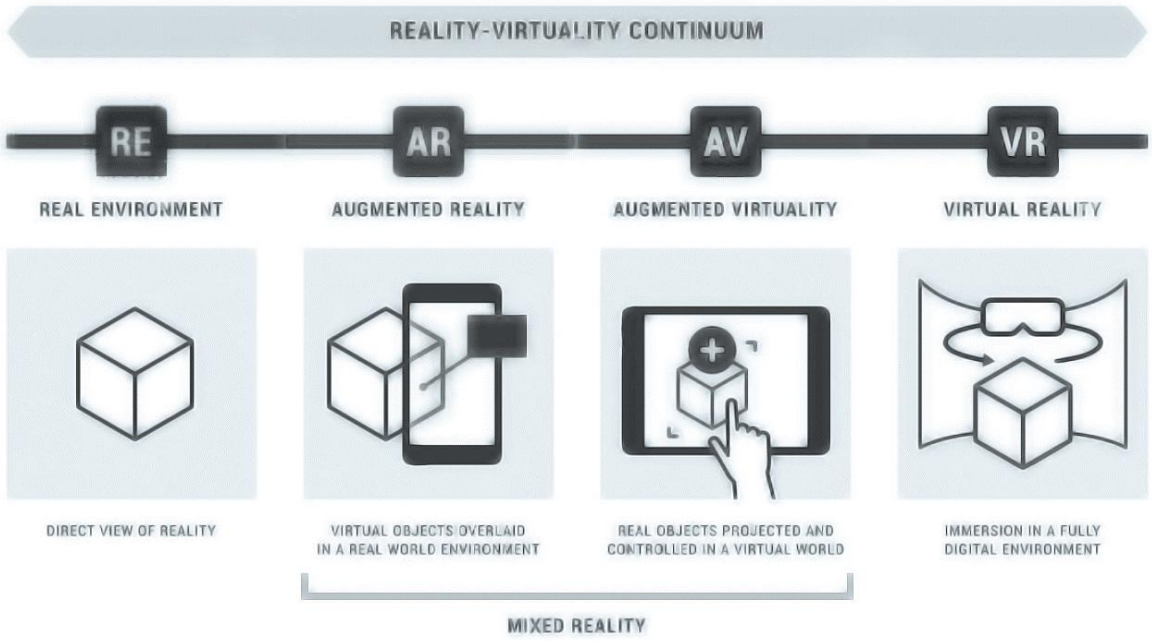

figure 4 Differences between AR, MR and VR (Immersion Levels)

II. BACKGROUND

VR has found its place in numerous professions including, but not limited to, science, sports, and filmmaking. This leaves a great deal yet to be understood about VR's place within the architectural field. Specifically, we are presented with the need to determine the best way to integrate VR into the architectural design process. Gartner Inc. has stated that within the next five years, VR will reach "technological maturity". Within this timeframe, it is imperative for the design field to discover new ways to utilize the capabilities of VR and move the architectural practice forward. VR developers constantly emphasise how real and visceral a VR experience feels.

With the praise, VR technology receives, a discussion of the medium's shortcomings within the architectural practice is often left undocumented. There is a need to verify the viability of VR in the three disciplines of concern–architecture, spatial planning and urban planning. To address this, this research aims first to judge the practicality of Virtual Reality within the architectural design field, before determining an assessment of how VR can best be applied within the architectural workflow. The goal is to determine how VR might be able to change the way architects learn, play, and communicate designs. VR also carries the potential to change the way that architects think about designs. In this regard, this research primarily focuses on the visualization aspect of the design process. Design visualization is how the architectural practice has communicated any work that is in progress to teams, clients and other architects. It is integral to the process architects use to think through ideas, resolve problems and make decisions within a project.

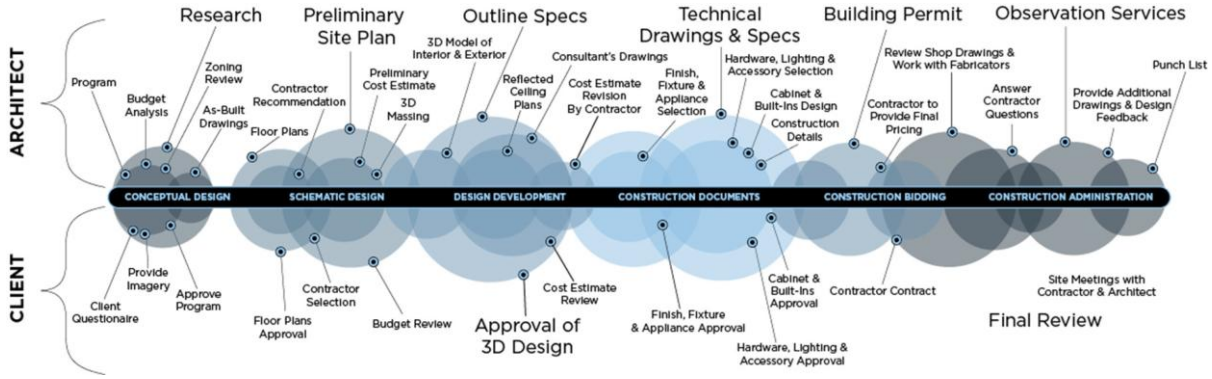

figure 5 Design Stages & The Architectural Process

RELEVANCE OF VR IN THE ARCHITECTURAL FIELD: COMMUNICATING INTENT

In 1968 Coons stated in his New York Times interview, "*In a few years from now you (a group of architects) will be able to walk into a room and move your hand and have a plane or surface appear before you in light. You will be able to build a building in light so that you can walk around it and change it*" (Herzberg, 1968).

The design process and the design communications during the stages can be envisioned simply through the VR head-mounted displays (HMD) by their ability to engage visual immersion. Michael Abrash, Chief Scientist at Oculus asserts that "the human perceptual system has evolved to capture massive amounts of data from our environment." Yet, only a small fraction of that capability is utilised today.

Since the time of those drafting tables and manual renderings, literature, and physical models, human cognition was capable of reconstructing the missing pieces of the puzzle for the full experience. But with the fully immersive experience brought by the VR, beyond cognitive understanding, the sense of spatial perception is engaged.

IMPORTANCE OF VR IN THE ARCHITECTURAL FIELD: PRESENCE AND PROPORTIONS

The two main aspects separating traditional visualisations from Virtual Reality experiences are presence and proportions. Presence, also relating to experience, implies the subjective feeling through a generic set-up inside a virtual space. It transports the user from real-world experiences to the virtual world. Since this feeling, as aforementioned, is subjective, tends to be volatile and fragile for each user, and can make one seem lost, and claustrophobic, rendering it unviable for architectural practice too. Also, allowing users to experience the grandeur of a skyscraper or a cantilevered bridge hovering over a cliff at its true scale is a major step towards architectural communications. However, these two factors are not guaranteed in every VR experience, given its complexity and details.

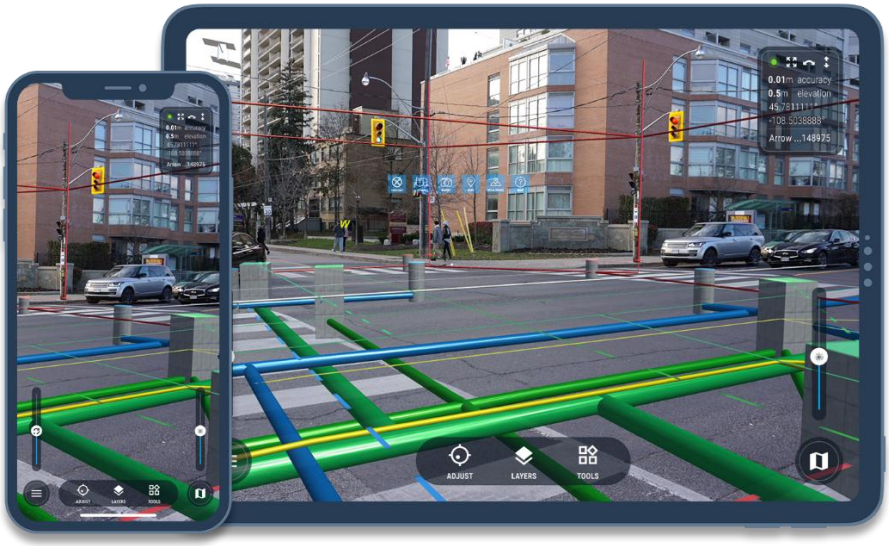

figure 6 3D interpolated GIS using Augmented Reality

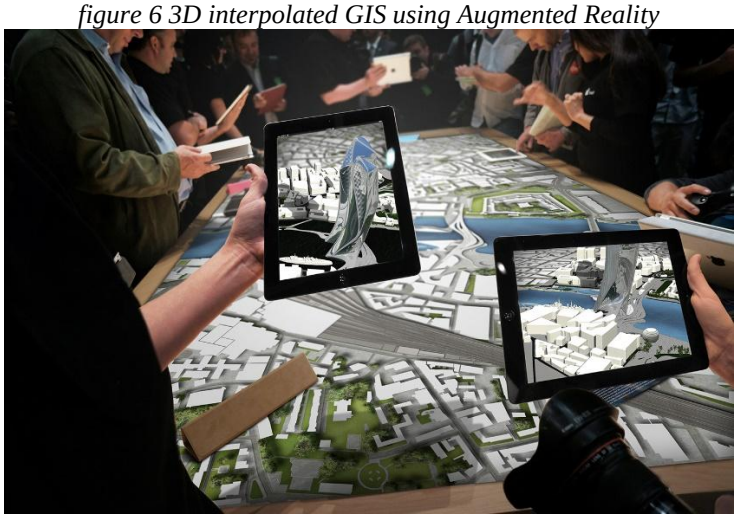

figure 7 Urban scale developments visualised and experienced using Augmented reality

Visual perception gave rise to the subjective assessment known as a spatial experience. The components of the human visual system, according to Mihelj et al. (2014), include
The perception of light, the perception of sound, and the perception of depth and colour.

VIRTUAL REALITY HARDWARE

Current consumer-based headsets in the market fit between two categories; mobile or tethered. Mobile headsets are simply shells with lenses into which a smartphone is placed. The user while able to view and hear the VR simulation, will not be able to physically move anything but their head to access other views within the rendered scene. Hence, this experience is physically stationary as the user will remain seated or standing for the majority of the experience.

Experiences that track this physical position along with head rotation are referred to as room-scale VR experiences. Room-scale experiences are created with tethered headsets, which come with built-in motion sensors and external hardware in the form of camera trackers to allow for a more complex VR experience. Tethered headsets such as the Oculus Rift and HTC Vive are connected to personal computers (PCs) and are able to place all the computational load of video processing into the PC itself. A room-scale VR experience thus offers more promise in assessing applicability in architecture as it allows a user to freely walk around their play area of VR space, translating physical movements from reality into their digital environment.

figure 8 Leading VR Headsets

Mobile VR Systems	Samsung VR Gear	Google Daydream	Google Cardboard
MRP (as on 2022)	□ 7,279	□ 2,985	□ 150
Platform	Android	Android	Android, iOS
Experience	Stationary	Stationary	Stationary
Field of View	101 degrees	90 degrees	variable (90 degress)
Resolution	1440 x 1280 Super AMOLED	variable (Pixel XL 1440 x 1280 AMOLED)	variable
Headset Weight (g)	317.51	220	90.7
Refresh rate (Hz)	60 Hz	variable (min 60 Hz)	variable
Controllers	Headset touchpad, single motion controller	Single motion controller	Single headset button

Table 1 Mobile VR Systems

Tethered VR Systems	HTC Vive Cosmos	Oculus Quest 2	Windows Mixed Reality	PlayStation VR
MRP (as on 2022)	□ 1,08,000	□ 39,399	□ 24,999	□ 41,999
Platform	Windows, Mac	Windows, Mac	Windows, Mac	PlayStation 4
Experience	Stationary, Room Scale	Stationary, Room Scale	Stationary, Room Scale	Stationary
Field of View	110 degrees	110 degrees	variable (100 degrees)	100 degrees
Resolution (per eye)	1080 x 1200 OLED	1080 x 1200 OLED	variable (1440 x 1440 LCD)	1081 x 960 OLED
Headset Weight (g)	544.311	635.029	170	589.67
Refresh rate (Hz)	90 Hz	90 Hz	variable (60 Hz - 90Hz)	90 Hz - 120 Hz

Controllers	Dual motion wand controllers	Dual motion controllers	Dual motion controllers, inside-out tracking	Dual PlayStation move controllers

Table 2 Tethered VR Systems

APPLICATIONS

- *Virtual Reality and GIS: Applications, trends and directions* Mordechay E. Haklay,2011 describes the results of comprehensive literature and Internet survey on current trends in Virtual Reality GIS (VRGIS). With real-time and seamless integration and data interpolations, live Urban models for the Geographic Information System can be generated and are in the process of groundbreaking technology soon.
- Virtual Heritage: The development of digital media technology offers enormous possibilities for the photo-realistic recreation of monuments or heritage sites that are important to the culture. VH is a new area of study. It has already proven some potential for preserving digitally and educating the public about history. However, current tendencies in interpretative practice appear to be strongly driven towards 'wow' centred rather than user-centric approaches. *Virtual Heritage: Exploring Photorealism,* Hafizur Rahaman, 2012

VIRTUAL HERITAGE:

Referencing from the works of Erik Malcolm Champion from Curtin University, in his *"Virtual Heritage: A Guide",* several kinds of research and certification courses on this very topic of Virtual Heritage are available to many enthusiasts to bring past to present. With the help of information technology and artificial intelligence in terms of discovery, recording, restoration, analysis, intervention, interpretation and transmission of Yester years human creations, the traditional goals of cultural heritage can be practically perceivable and achievable.

Such tools available hone one's ability to conceptualize and demonstrate to develop new and compelling solutions to important problems in the fields such as

- Anthropology
- Archaeology
- Conservation
- Exhibition design
- Egyptology
- Art and architectural history

Steps involved in this Virtual Heritage are:

1. 3D Reconstruction in Archaeology for speculating the past
2. Photogrammetry involving preliminary documentation and 3D reproduction
3. Mapping Ancient Heritage Narratives and linkages with Digital Tools
4. Evaluation of data and in Virtual Heritage
5. Hybrid Interactions for Museums
6. Preserving Authenticity to pass on the rightful culture and heritage values to future generations

VIRTUAL REALITY IN GIS:

Mordechay E. Haklay in his *"Virtual Reality and GIS: applications, trends and directions"* derives the applications of virtual reality as VRGIS and its potential development and future directions based on the current practice observations and research projects during the last decade merging Virtual Reality and Geographic Information System (GIS).

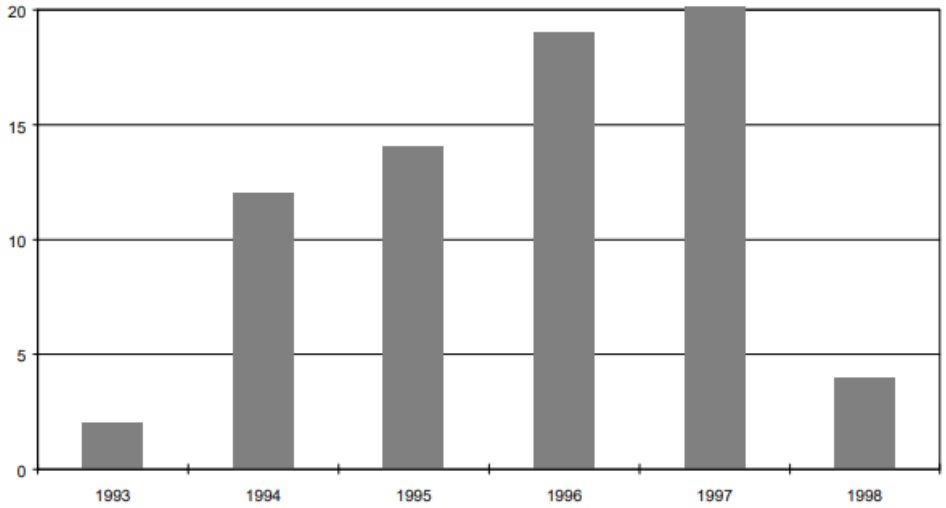

table 3 Virtual Reality and GIS projects initiated 1993-1998

Ever since then, there has been a rapid growth of practical application of Virtual Reality in Geographic Information systems over the span of the next 3 decades. Of those applications, the emphasis is on assessing the visual impact of different planning schemes hold the largest share (about one-third) in the fields of GIS and Urban planning.

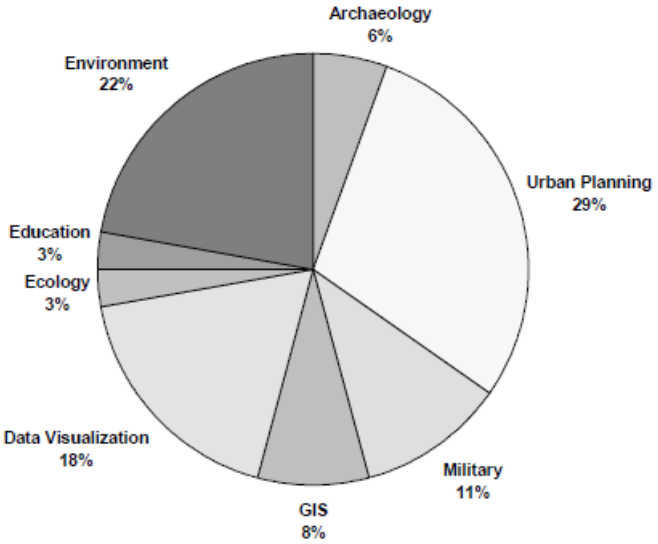

figure 9 Virtual Reality and GIS projects by research area

Properties of VRGIS are

1. Hyper-realistic representation of real geographic areas;
2. Free movement within the selected geographic terrain; and
3. Standard GIS capabilities in a 3d environment;

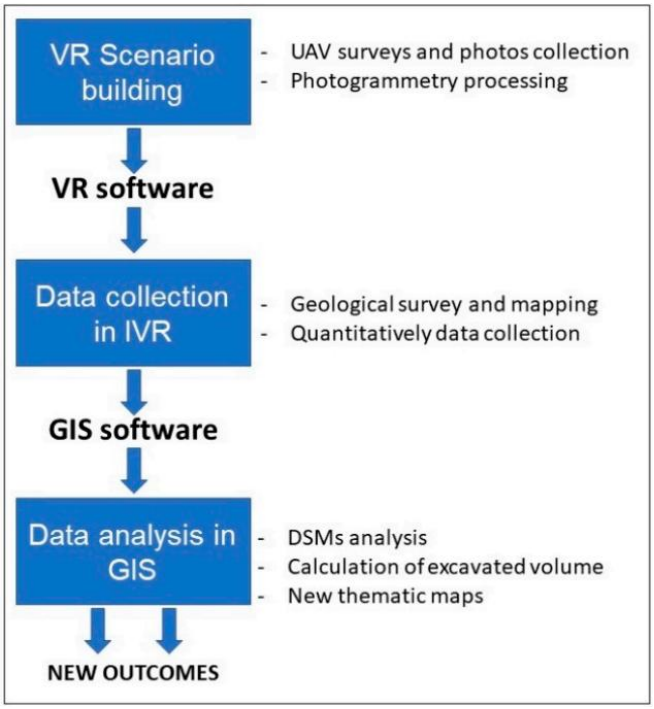

figure 10 Overall conceptual workflow used in the present work

III. LIMITATIONS

To conclude, there are some open questions, worth mentioning and interesting, viz.,

- The role of 3D raster and its potential usage over generic 2D raster layers;
- The possibility of seamless integrations between several users and contributors to develop statistical and analytical data visualisations for policy-making and resource management;
- The coalition and collision of data collection methods for conventional GIS methods and modern VRGIS methods;
- GIS illiteracy influencing the delivery and usage of VRGIS for mass human interactive models;

Apart from the specific field of study, in general, VR has not passed from being owned by a niche market, although it is readily available in the consumer market. In order to reach the untapped market and become a user-friendly product, it needs to gain traction in availability and accessibility. Without compromising on affordability to create this immersive experience, the hardware has to be intuitive and offer an experience beyond the thinkable. By current market availability and standards, not all VR gears provide the same experience, like lack of motion control or gesture control. Invented as an entertainment gadget, and used in research in several fields, developing it to be a recreational tool is a challenging task. Beyond visual and auditory, other sensory experiences like haptic feedback, are in development. Movement beyond a single room, and travelling larger distances without teleportation is difficult. Even though accessing teleportation, a user has to have a large empty physical space in the room to experience the visualization of a small room without bumping into physical objects. Each scene also requires the creation of digital barriers (or colliders) to prevent a user from exhibiting "ghost-like" tendencies in the simulation.

Overall, VR walkthroughs require users to physically travel much farther than what their physical space can generate.

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