Virtual reality based novel use case in remote sensing and GIS

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Virtual reality (VR) is realistic, interactive and immersive 3D computer generated world that one can explore as if one is present in the scene. VR makes it possible to experience anything, anywhere and anytime. Head mount device (HMD) with headphones and hand controllers are used to provide fully immersive experience. There are three important I's in VR; interactivity, immersion and imagination. Virtual reality is stepping in each and every domain like engineering, science, military, education, medical, tourism and entertainment. We have explored its potential for usage in remote sensing and Geographical Information System (GIS). Usually, GIS users analyse remote sensing data such as high resolution images, digital elevation models and vector data in commercial and open sources 2D GIS software(s). Available GIS software(s) allow users to interact with remote sensing data as a third person only. We have developed in-house virtual reality solution to generate a 3D terrain using high resolution imagery and elevation models over Earth. User can move around or teleport to different locations inside the 3D scene and interact with real time objects available in the scene.

Keywords: Geographical Information System, head mount device, immersive nature, remote sensing, virtual reality.

IN recent times, using stereo and aerial photogrammetry high resolution Digital Elevation Model (DEM) is being generated at a very fine grid interval. Ortho-imagery is also obtained after the processing of raw imagery using DEM and other important parameters. Inputs of DEM and ortho-image are widely used to construct 3D textured surface model over a given place over Earth using various SW and tools. People are using this 3D textured surface models to assess and to carry out measurements remotely and able to gain insight into local geography of the given place. Web 3D models are provided by Google Earth, Cesium JS and Bhuvan like web platforms, whereas multi-screen SW visualization solutions developed and copyrighted by ISRO are also available to render 3D surface planetary datasets. Virtual reality (VR) is gaining popularity because of immersion and interactivity with the scene as a first person and also due to its applications[1] in education, training, simulation, entertainment, military and engineering fields. In military, a pilot can be trained with a flight simulator. VR is not only used for vehicle simulation; but it can also transport the soldier in a specific virtual environment where they are faced with a certain scenario to which they must decide the next course of action. VR offers many opportunities to teach a subject to students or even adults. The immersive nature of VR has been identified as a tool that facilitates the learning process. Some field engineers are using virtual reality as a part of the design process; this allows them to see their prototype in 3D to obtain a better understanding and detect flaws, quickly and easily improve the overall quality of the concept. VR and augmented reality (AR) are good answers to the issue of facilitating mobility. It also enables the user to visualize a path that is superimposed onto an image of their real, observed environment on a smartphone or a tablet. VR is a strong marketing tool for the tourism industry, giving them the opportunity to attract more potential customers by offering a more compelling image of the destination, giving them a taste of what it is like to be there. VR for the simulation, planning and training to carry out operations: navigational help; AR devices; remote interventions; robotics, computer-assisted surgery is a growing field. The entertainment industry is also the biggest producer of virtual reality content and is most often related to the gaming industry.

If we see historic evolution of VR, before 1960, numerous approaches and methods were perfected before the birth of 'virtual reality' as a field. During 1960–1980 the emergence of computer sciences enabled the development of all the elementary components that led to the advent of virtual reality. From 1980 to 1990, technology was developed specific to 3D interaction, in particular. During the 1990–2000 decade, integration of material and software solutions made it possible to implement experimental applications that were credible and operational. During 2000–2010, after having focused on product-design and learning how to drive vehicles, the applications of VR evolved towards maintenance and training, using simulation to control industrial processes[2]. From 2010 onwards, this last period was marked by the arrival of new equipment at costs that were much lower than those of earlier devices, while also offering a high level of performance[2]. This made it possible for 'new' developers, to independently develop their solutions. It is clear that this is just the beginning of VR–AR becoming accessible to the general public. We have also witnessed some real case studies using virtual reality in various fields in recent times. Google Earth VR[3] is the project in which they have implemented virtual reality technology on data available as a part of google earth. Here, a person can be moved to any part of the region in the globe and see the world in the form of a 3D textured model. This solution is streamed online through web. Hurby *et al.*[4] studied spatial presence in immersive geo-environments, a VR replica of a coral reef in the Mexican Caribbean build upon world view-2 imagery. Gürcan Büyüksalih *et al.*[5] have used VR for immersive and interactive visualization of the Incegiz caves in Istanbul. David Li and

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team[6] at the university of Maryland developed MeteroVis system to visualize meteorological events and data in virtual reality.

We have developed an offline VR solution in the domain of remote sensing and GIS. SW solution takes high resolution DEM and orthoimagery generated through satellite imagery or aerial imagery as basic building blocks and generates a textured surface model of the given place with different level of details. In-house SW solution is developed in such a way that it works on popular HMD devices like HTC Vive and Oculus. User has a feeling of complete immersion and can interact with various objects on the surface. User can climb mountain region, has beautiful view of river side or can teleport to different scenes in the solution. Whole user experience can be recorded using the SW. This solution provides user a complete package to visually access and analyse the geography of any site. Altitude of the place can be figured out using the click of HMD button on the rendered surface.

High resolution image dataset is the prime requirement for virtual reality solutions. As one wants to analyse the geographical area as a first person, if served data is coarser in resolution, it will not look appealing and will give a bleak scenario. We have three level of details in our solution. So, based on the level of details/distance of the viewer from the scenario we have populated three different datasets as given below.

- Digital elevation data: We have mainly used offline DEM data over the places. DEM data is downloaded offline from Carto1DEM-10 m (ref. 7) using Bhuvan platform, SRTM 30 m DEM from USGS site[8]. Wherever better than 5 m are available, we have used that data.
- Imagery data: We have used image data from Indian remote sensing satellite of Cartosat-2S which has a merge product with spatial resolution better than 1 m. We preferred use of these datasets on level of details-2 where we are providing bird-view kind of visualization. Further, for finer level of details, we have used very high resolution offline images from Microsoft Bing maps[9].

In order for the human brain to accept an artificial, virtual environment as real, it has to not only look real, but also feel real[10]. Broad level system architecture diagram is shown here with basic building blocks of VR. In VR environment, it starts with user decision of executing some tasks; task is assigned by user through input devices to VR engine which through SW processing performs the given task in real time and presents rendering and simulation. Further, based on the rendered output user can issue new commands.

Video is sent from the console or computer to the headset via an HDMI cable in the case of headsets such as HTC's Vive and the Oculus Rift. VR headsets use either two feeds sent to one display or two LCD displays, one per eye. There are also lenses which are placed between eyes and the pixels. These lenses focus and reshape the picture for each eye and create a stereoscopic 3D image by angling the two 2D images.

Head-tracking implies while wearing a HMD, the scene in front of user's eye will shift as user looks up, down, side to side or angle his head. There is 6 degrees of freedom according to the head movement in X, Y and Z axis to measure head movement in roll, pitch and yaw direction. There are internal components available in head tracking system such as gyroscope, accelerometer and magnetometer to measure the head tracking.

Lighthouse positional tracking system involves two base stations around the room which sweep the area with lasers for tracking motion in case of HTC Vive. These can detect the precise position of head and both hands based on the timing of when they hit each photocell sensor on both the headset and around each handheld controller[11]. Head mount device, head tracking and motion tracking system work in tandem to provide virtual world experience with user interactions as shown in Figure 1.

There are multiple head mount devices from vendors like HTC Vive[12] and Oculus rift[13] and SW framework such as unity 3d (ref. 14) and unreal game engine[15] available for development of virtual reality applications. Initially, we have used unity 3d as a SW framework and HTC Vive as head mount device for our developmental work. After development, we have tested our SW on both the HMD devices, HTC vive and Oculus rift, and SW performs equally well on both these devices.

Users are able to analyse remote sensing datasets such as high resolution images, digital elevation models and vector shaper files using available GIS software. Currently, most of the remote sensing and GIS user community is mainly using solutions, namely QGIS[16], ArcGIS[17] software for analysis of the remote sensing datasets (imagery and DEM) and vector layers. In these cases, GIS software is installed on a computer machine/workstation and user performs all the analysis mostly on 2D raster layers. By putting in special efforts, users can also generate perspective view of surface terrain models of the place. Perspective view of the terrain model aids users to analyse and assess geographical location as a third person.

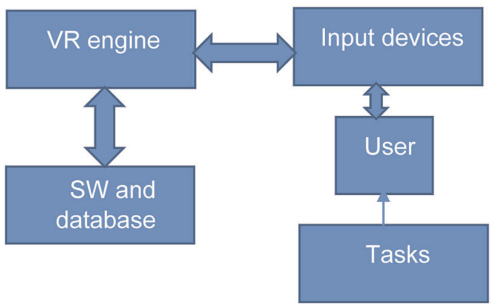

Figure 1. Virtual reality (VR) system architecture.

As a part of new development, we have proposed a virtual reality based solution to analyse in interactive and immersive fashion. In this case, users are immersed into 3D scene where user can have a feel of heights and depths of the places. User can move around in the scene or teleport to different locations. Users can have different views from mountains tops, valleys and can also interact with various objects. Using this SW, user can experience complete geography of the remote area by putting on the HMD device. Users will be visually analysing various situations on ground. We have developed a novel VR solution which takes high resolution digital elevation model and imagery over Earth as an input and generates a 3D mesh of the corresponding area. We have developed virtual reality supported software solution in unity 3d framework with the following key aspects.

- One can ingest DEM of any resolution and size; imagery of any resolution of corresponding area.
- Supports generation and visualization of 3D terrain using input data of any resolution and size.
- Supports navigation in all the directions.
- Supports manoeuvring by teleporting to specific areas.
- Support displaying height information over teleported places.
- Different level of details as per the altitude.
- Recording of full scene as a video.
- Interpretable on Windows and Linux operating systems.

SW solution has major applications in disaster management, smart city, infrastructure planning and for strategic usage. Using this SW, one can experience interaction with various objects using number of transformation in virtual world. Disaster recovery teams and strategic users will be able to plan thoroughly for key operations. SW can also be used for infrastructure management, tour planning as well as for education purpose.

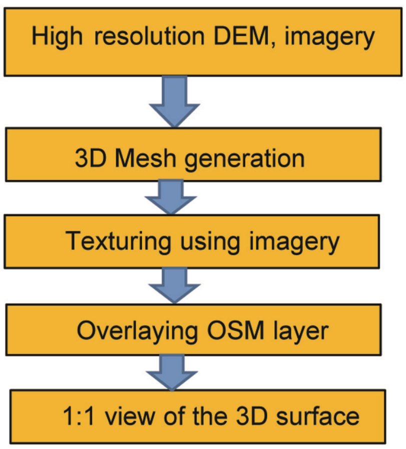

Figure 2. SW workflow diagram.

For complete workflow we have taken satellite data (DEM) in binary and (imagery) in jpg/png format as an input to SW. We have generated 3D Mesh using input DEM data. Image texture is draped over 3D Mesh and realistic scenario over a place is generated. Further, OSM layer of naming convention is overlaid on the top of the 3D scene for information. SW is enriched with features of teleporting, display of altitude information and enhanced details according to the viewer and object distance. SW workflow is shown in Figure 2.

Using the SW solution, users are able to select area of interest and can transport to the specific location on the globe. In the level of details-2, users experience bird eye

Figure 3. Level-2 view over Pangong Lake.

Figure 4. Aerial view of VR scene over hilly area.

Figure 5. Ground level view of Valley area. It feels as user is standing near buildings. Pointer displays the height of the place in meters with respect to latitude and longitude

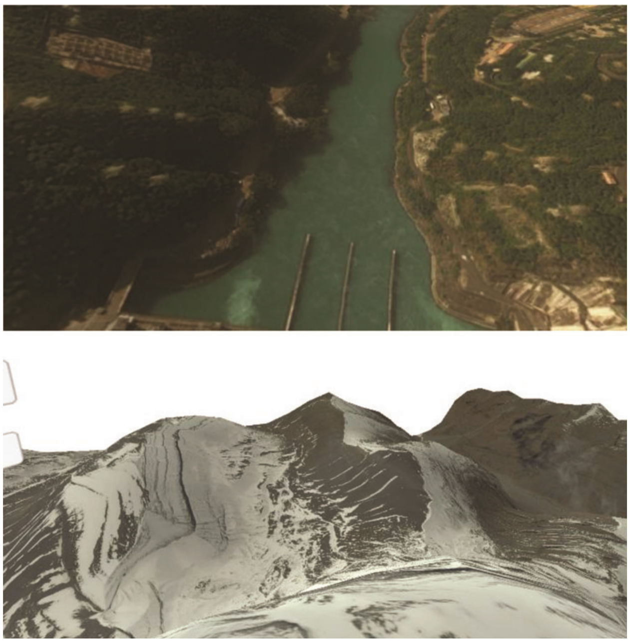

Figure 6. Aerial view of dam area and Mt Kailash in VR.

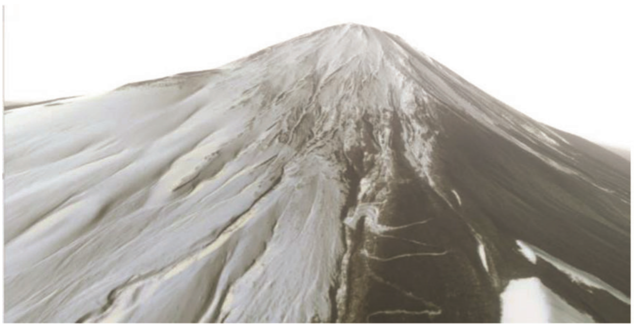

Figure 7. View of mountain Fuji as a first person in VR.

view over the place using satellite imagery as the base layer whereas in level of details-3, users experience first person/ground level view of the place. Person is able to move around and check the height of the surface along with latitude and longitude information. We have captured the various screen shots of different parts of the globe using developed solution. Figure 3 is an aerial view of Pangong lake as seen in immersive manner whereas Figure 4 is a coarser view (level of details-2) over a hilly region. Figure 5 represents the ground level details over a valley region and altitude over the region is shown using pointer. Figure 6 shows the aerial view of a DAM area and Mt. Kailash. Figure 7 displays side view of the mountain Fuji.

In this communication, we have explained, virtual reality technology, its working principles and its potential application in the field of remote sensing and GIS. An in-house VR software solution has been developed which takes high resolution digital elevation model and imagery over Earth as an input and generates a 3D terrain of the corresponding area for better analysis and assessment. Developed solution helps remote sensing users to dive through the data generated in computer environment in an immersive and interactive manner. Users are able to teleport to multiple location, measure heights of the surfaces and able to visually assess the prominent features over the globe. Further, there is vast scope to implement VR for planetary data such as Mars and Moon using high resolution datasets. Virtual reality solution using planetary data will be helpful in visual analyses of landing areas, study sites and play a crucial role to visualize the actual size and shape of the various important features. In the near future, we plant to explore ways to create immersive and interactive view over entire globe using satellite data and advanced head mount devices.

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