Immersive Data Interaction for Planetary and Earth Sciences

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ABSTRACT

The Multimission Instrument Processing Laboratory (MIPL) at Jet Propulsion Laboratory (JPL) processes and analyzes, orbital and in-situ instrument data for both planetary and Earth science missions. Presenting 3D data in a meaningful and effective manner is of the utmost importance to furthering scientific research and conducting engineering operations.Visualizing data in an intuitive way by utilizing Virtual Reality (VR), allows users to immersively interact with their data in their respective environments. This paper examines several use-cases, across various missions, instruments, and environments, demonstrating the strengths and insights that VR has to offer scientists.

Index Terms: H.5.1 [Artificial, augmented,and virtual realities]

1 INTRODUCTION

A fundamental challenge that faces all scientists, is finding a meaningful method to convey a message with their data. As a result, data visualization has become an important component of the scientific endeavor, with standards and nuances unique to each individual field. 3D data has proven especially challenging to visualize meaningfully, and dynamically. However, recent advances in VR technologies have created an opportunity to develop new techniques and build a new generation of tools and interfaces for scientific applications.

Home to many scientific missions that generate 3D data, JPL has developed a deeply rooted interest in providing the scientists and mission operators with the best visualization tools available. The discussion will survey a number of recent efforts in support of various science teams, which speak to the advantages that VR has to offer as a practical scientific tool.

In high-risk missions, a visualization's fidelity (i.e. staying true) to the highest detailed data must be preserved. Misleading renderings of the data could thwart scientific progress and makes operational planning unsafe. For these reasons, visualizations must retain the original color, geometry, and resolution of the data.

Secondly, since there is a diverse set users for these tools, the tools should be easy to deploy and use. The applications should be ambivalent to the user's working environment, and the learning curve should be small. If there are tools already available for the project, the applications should act as an extension of the existing tools rather than a replacement.

Game engines were found to be the simplest point of entry, and were leveraged for both their graphics performance and ability to build for multiple platforms immediately. Additionally, the game engines typically contained physics engines, which were used to simulate interactions within the environments. This is an acknowledgement to the availability of resources for deploying modern VR applications of high quality.

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2 APPLICATIONS

The following projects have begun to utilize VR for data visualization and interaction. Each project presents unique data types and interests, many of which were described and discussed by Kreylos et al. [2]. However, due to the nature of the data, the focus below will explore the nuanced and specific needs of each mission and discuss the gains VR brings to visualizing and interacting with the data.

2.1 Mars Science Lab

Mars Science Lab (MSL) successfully landed the Curiosity rover on the surface of Mars in August of 2012. Aboard the rover were 16 cameras, mostly organized in pairs to capture stereo-images. The paired cameras take photos simultaneously a known distance apart with over-lap in the subject. Analysis of these images allows a MIPL pipe-line to extract geometric properties of the environment and generate different types of data products, ranging from mosaic panoramas, to point-clouds. Of particular interest, the point-clouds are also fitted with triangular polygons to render 3D terrain meshes, modeling the local environment.

Rover operations specialists view and utilize the meshes for rover traversal and arm motion planning in the Rover Sequencing and Visualization Program (RSVP)[9][5][4]. During operational planning, meshes are loaded into RSVP along with a model of the rover for planning and simulation (e.g. obstacle avoidance).Previously RSVP limited interactions with the terrain data to an external view, often removing the intuition that a planner might have about a scene. Furthermore, planetary scientists are limited to interaction through still frames and screen-captures.

Previous orbiter and rover missions imaged large portions of Martian terrain. Blindly overlapping the generated 3D meshes that are geographically correlated will contain lower resolution meshes protruding over higher resolution meshes. Often this issue are a result of rover images having obstructions in the field of view (FOV). Gaps are left empty as to preserve the fidelity of the data and the available tools were unable to handle this case so lower resolution meshes were omitted in order to interface with the higher resolution meshes.

Utilizing the "Shaders" interface available in the game engine the terrain is visualized, rendering the higher resolution mesh after rendering lower resolution meshes in the FOV thus ensuring promotion of higher resolution meshes. This allows scientists and mission planners to see all of the data in as high detail as possible while preserving the broader geophysical context. Shaders can also be used to model light interaction of a material (i.e. reflectance and transparency) allowing shadows of the the rover on the terrain to be modeled, an important feature when planning rover imaging.

A Heads-Up Display (HUD) was used to expose specific data about user positions, FOV, and terrain data (e.g. gradient, coordinates, etc.), allowing scientists and planners to interrogate the available data more critically.

Rather than restricting the user to 360 stereoscopic panoramas and wall projections, users can interact and traverse freely within the environment, enabling them to observe detail in the terrain data from different perspectives. Further still, rover traversal paths can be imported, showing straight-line connection of coordinates corresponding to start and end points, mapping out the entire path of the rover from landing. The traversal can be viewed also through a locked Point-Of-View (POV) corresponding with the height of the rover, moving in accordance to the path loaded. This enables an understanding of what the rover encounters and produces an intuitive perception of the obstacles that arise.

Additionally, the rover can also be modeled and animated in the VR environment allowing a closer observation of the interaction and registrations between the rover and the terrain. By overlapping an animation of the predicted motion and an animation reconstructed from rover telemetry data, discrepancies become easier to detect.

2.2 Oceans Melting Greenland

Started in 2015, Oceans Melting Greenland (OMG) examines and evaluates the causes and effects of melting glacier fronts in Greenland. OMG's initiative is to understand the impact melting glaciers have on the surrounding environment, and find methods of conserving the fjords.

A modified G-III plane flies over the coastal front, generating high precision elevation measurements with the Glacier and Ice Surface Topography Interferometer (GLISTIN). GLISTIN flyovers are conducted every spring to track annual glacier thinning and retreat, while 250 temperature and salinity probes are deployed along the continental shelf in the summer.

Gravitational field observations, and sonar scanning of the ocean floor, give scientists a geometric understanding of the environments. The seasonal data collected can then be displayed in conjunction with geometric observations of the local terrain, contextualizing the data and allowing scientist to model ocean/ice interactions, and estimate with higher accuracy how glacier melting affects the global sea level.[8]

Many of the needs that OMG science teams from VR integration were available from MSL. Namely, a textured terrain was extrapolated from point-cloud data, and projected in a VR environment that was open to exploration via fly-through. However for OMG the terrain is simply a single 3D mesh to which data is mapped. Only one mesh needs to be generated and "materials" with mapped data (e.g. glacier velocity, water/ice masks, etc.) are applied to it.

The availability of hand tracking controllers during development, allowed a simpler more immersive user interface was developed. Extending on the work described by Pick et. al [6], users could gesture to point out key features, then pin them on the surface, recording positional data and adding annotations. All of these data points can then be saved to an auxiliary file and shared with collaborators or used in other applications.

2.3 Atmospheric Infrared Sounder

The Atmospheric Infrared Sounder (AIRS), utilizes an infrared scanner to measure and classify meteorological activity in the troposphere and stratosphere. [1] AIRS uses hyper-spectral sensing to retrieve the Effective Cloud Fraction (EFC) and cloud top pressure (CTP) for up to 2 cloud layers. The data spans 15 sq.km granules and characterizes the cloud's thermodynamic phase (i.e. whether the cloud is composed of ice or liquid). [3]

Typically the data was observed as 2D maps, arranged into slices at different heights, colorized by characteristics such as temperature, water-vapor, ECF or ice/liquid concentration. When comparing data across different instruments and data sets, cloud "curtains" were used to visualize a 2D slice.

Previously the AIRS science team did not have a method to visualize individual granules in 3D . Utilizing the existing infrastructure and experiences with previous VR projects, AIRS seamlessly integrated itself into the VR visualization tool, and gained a new valuable asset for science.

AIRS data is recorded as an average over a volumetric sample and is visualized as a cylinder with an XYZ coordinate corresponding to cloud height, and a radius which is tied to the cloud fraction. Different colorings of the clouds represent cloud composition or classification. Data about water vapor and temperature is derived as an average over 9 adjacent samples, typically rendered as circular disks on a map. Introducing layer-based adjustable transparency (again using Shaders) allows scientists to observe trends when dense cloud formations and vapor data are projected together.

3 Conclusion

The immersive nature of the VR, separates it from other forms of 3D visualizations. Recent advances in VR has enabled applications similar to those described above to be developed more rapidly, and practically for scientific purposes. Additionally the richness of the available data from JPL enables an immersive experience with a nearly unlimited "field of regard"(i.e. the number of directions that a user can look and the positions they can look from).[7] As a result scientists and mission operators are able to focus on their specific interests without losing the broader context of the data.

In the realm of planetary sciences, simply collecting the data is a significant impediment to the scientific process. There is an imperative need to expedite the process, and remove as many limiting factors as possible. One such limitation is the ability of scientists to make observations and insights once the data is available to them. For many years new advances in visualization have helped scientists see deeper into their data and VR's capabilities have demonstrated a tremendous capacity to enable the scientific process. True 3D visualization, allows scientists to analyze, question, and learn, ultimately pursuing the mission to "reach new heights and reveal the unknown for the benefit of humankind."

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