Public Dissemination of Celestial Bodies Using Spatial-Temporal Map Data

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Abstract— The mapping of the planets and moons within our solar system is carried out by space organizations such as NASA and ESA. Image data are collected by instruments on satellites and spacecrafts, and used in scientific research and mission planning. While map data from space missions are often shared openly, it can be difficult for non-experts to comprehend the context of the data and understand the acquisition process. We present an application where scientific mapping data of celestial bodies is shown in a visualization suitable for public dissemination.

By combining various types of datasets and visualization techniques, we are able to contextualize map data spatially and temporally. A chunked level of detail approach is used to enable interactive exploration of global maps as well as high resolution local digital terrain models with texture and height information. This is particularly interesting for Mars due to the extensive amount of map data gathered by the various missions on this planet. Using time varying data sets, we can visualize the dynamics of a celestial body, such as weather conditions on Earth. Furthermore, we can interactively playback in-situ visualizations of the data acquisition process.

Our work has been implemented in the open source software OpenSpace, enabling interactive presentations in immersive environments such as dome theaters and VR-headsets.

Index Terms—Radiosity, global illumination, constant time

1 Introduction

[-Kalle- Maybe some more catchy name of the article? "Browsing the Red Planet", "Browsing Mars", "Unveiling Mars"? :P **]** **[-Emil-** Public dissemination of celestial bodies using spatial-temporal mapping-data ? **]**

1. Visualizing space data is important because its expensive

   [-Kalle- What is expensive? **]**

2. There exists a vast amount of data from Mars orbiters

   The amount of data currently available from various space missions is extensive. NASA alone offers more than 100 TB of images from various planetary space missions through the Planetary Data System, which is available as open data.

   [-Kalle- `https://open.nasa.gov/blog/what-is-nasa-doing-with-big-data-today/` **]**

   NASA's Viking program, launched in the year 1975, gathered important information about Mars and its surface features from the two orbiting satellites and the landers put on the surface of the planet. Today, the most important large scale imaging campaign is carried out by the Mars Reconnaissance Orbiter (MRO). This satellite carries the MARCI (Mars Color Imager), CTX (Context Camera) and HiRISE (High Resolution Imaging Science Experiment) cameras which are used to image the surface at different resolutions.

   [-Kalle- `http://pds-imaging.jpl.nasa.gov/portal/` **]**

   Our goal is to, using visualization, bring space science to the public as well as providing tools for scientists to talk about space research. Part of this relies on the ability to visualize planetary science by providing an accurate representation the globes in our solar system as well as the ability to go there virtually, using the open data available from various space missions.

3. Missing spatial understanding from looking at pure images

   [-Kalle- any fancy visualization terms that I don't know about which can be used? **]**

   Raw image data, gathered from space missions, is easily visualized flat on screen. However, since ...

4. Contextualization of scientific data (being able to show satellites in the same context as surface features), (domes, vr headsets, etc)

   Using the tools that scientific data visualization allows, it is possible to get a better understanding of the space missions. By allowing contol of time flow, showing satellites and space probes in the same context as the planets, and doing this using immersive display systems gives intuitive understanding of the space around us and how scientists gather knowledge about it.

   Typical examples of use cases for interactive visualization are large scale dome presentations of real time presentations, virtual reality headsets, and touch tables; where the audience can experience flight through space and time, experiencing our current mapping of the cosmos.

5. Stereoscopic reconstruction from multiple image passes

   [-Kalle- Maybe not suitable to put here already? **]**

6. What datasets are available (Viking, MOLA, CTX, HiRISE) and whats their resolutions

   [-Kalle- MDIM 2.0 (references available): `https://astrogeology.usgs.gov/maps/mdim-2-1` **]**

   [-Kalle- Colorized Viking global: `https://astrogeology.usgs.gov/search/map/Mars/Viking/MDIM21/Mars_Viking_MDIM21_ClrMosaic_global_232m` **]**

   [-Kalle- MGS MOLA (references available): `https://astrogeology.usgs.gov/search/map/Mars/`

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Manuscript received xx xxx. 201x; accepted xx xxx. 201x. Date of Publication xx xxx. 201x; date of current version xx xxx. 201x. For information on obtaining reprints of this article, please send e-mail to: reprints@ieee.org. Digital Object Identifier: xx.xxxx/TVCG.201x.xxxxxxx

GlobalSurveyor/MOLA/Mars_MGS_MOLA_DEM_mosaic_global_463m]

[-Kalle- MRO HiRISE: https://astrogeology.usgs.gov/maps/mars-hirise-cameraandhttps://astrogeology.usgs.gov/missions/mars-reconnaissance-orbiter]

The Mars Global Digital Image Mosaic (MDIM) is a global image dataset with a resolution of 256 pixels/degree. This dataset is put together from images from the Viking Orbiter imaging system. The latest version of this image mosaic, MDIM 2.1 uses ...

[-Kalle- Mention latest coordinate system for Mars, IAU/IAG 2000 adoption.. Use of MOLA for correction etc.]

The highest resolution global color mosaic available for Mars today is still composed of images from the Viking missions. The latest version, compiled by NASA AMES, is warped to match the latest grayscale MDIM 2.1 mosaic.

The Mars Orbiter Laser Altimeter (MOLA) is an instrument on the Mars Global Surveyor (MGS) spacecraft. The digital elevation model (DEM) assembled from MOLA data maps each position on the globe with an offset from the Areoid, Mars' reference ellipsoid, to an average accuracy of +-3 m (ref). The dataset has a resolution of 463.0836 meters/pixel.

[-Kalle- +-3 m sounds too good to be true? Should check the reference.]

[-Kalle- Areoid: geoid but for Mars. Areography, Martian geography.]

[-Kalle- Other datasets? Does ESA have Mars missions of interest?]

7. How can this be applied to other planets, A system for enabling future research thati s correctly contextualized. What is the science question // What is the point of this

   By enabling the ability to read many types of image datasets, with global or local coverage, temporal or static, and doing so dynamically, we can generalize the technique to different globes without having a specific focus group. We hope that our tools can be useful both for scientists who want to present their work in a contextualized manner and for people who find interest in the subjects we discuss or want to experience the most accurate representation of standing on the surface of Mars using only real data.

Length: About 1 page

2 Related Work

Geographical Information Systems (GIS) relies heavily on the ability to gather, transform, and visualize data with geospatial information. Maps and DEM's are typical examples of such data and research and development of software solutions to handle different parts of GIS, such as rendering, have lead to different applications in space visualization. [-Kalle- Can Carter write something here? What other relevant softwares, like Google Mars, are in use?]

2.1 Rendering

A globe rendering system needs to handle out of core rendering and level of detail management to avoid flooding the data caches and rendering times.

Cozzi and Ring (ref) gives a thorough desciription of the most common methods used for globe rendering today.

2.2 3D Reconstruction From Images

Adding the third dimension required for terrain rendering is most commonly carried out by rendering DTMs, also known as heigh mapping. Height map datasets can be generated using measured data from altimeters on the satellites, corrected to match an offset from a reference ellipsoid (ref) in the direction of the geodetic normal for every point on the surface covered by the dataset (ref).

[-Kalle- Someone wants to add text about stereo reconstruction here?]

2.3 Geospatial Data Abstraction

Geospatial Data Abstraction Library (GDAL) is an open source software package and C++ library enabling re-projection and warping of map datasets and can act as a layer of abstraction between the rendering software and the many different types of map formats and projections.

1. the book

   [-Kalle- 3D Engine Design for Virtual Globes?]

2. terrain renderer
3. 3d reconstruction from images (stereoscopic and structure-from-motion)
4. GDAL
5. "virtual presence" systems
6. What else?

Length: About 1 page
Note: The page limit was increased to 9+2 pages this year (= 9 pages of manuscript, 2 pages of references). So we should make use of this and cite the hell out of everything that's related

3 Overview

1. What are the steps to get from a satellite to 3d terrain rendering
   (a) Acquision (MRO information)
   (b) Processing (AMES Stereo pipeline, ..., GDAL)
   (c) Rendering (Globebrowsing)
2. short descriptions for each

Length: About 2 pages

4 Image Acquisition and Processing

1. MRO information, different resolution levels
2. What are the available data products
3. Ames stereo pipeline
4. GDAL preprocessing

Length: About 1-1.5 pages

5 Rendering System

1. All the steps to get from GDAL to a rendering on the screen

   [-Kalle- Tile pipeline as described in our thesis (but shorter).]

   [-Kalle- Abstraction layers.]

   [-Kalle- Rendering chunks. Shader implementation on a high level.]

   [-Kalle- Atmosphere?!?!!?!]

2. Stereoscopic rendering
3. Dome rendering
4. Different resolution levels
5. Rendering rover locations

Length: About 2-2.5 pages (fill as much as the page limit (9+2) allows)

When the image datasets are in the format required for the renderer, there are several abstraction layers we employ to handle the out of core techniques required for rendering.

Two major concepts used in the rendering system are tiles and chunks. A tile has a texture representing a geodetic area and is uniquely defined by a layer and a tile index. A layer works much like in image editing softwares and can have different types, analogous to blending options. Examples are height layers, color layers, grayscale layers or grayscale overlays. A tile index is defined by a level, x, and y coordinates in the chunk tree structure.

The main globe model consists of a quad tree of chunks. The chunk renderer has access to a skirted grid (ref) which can be mapped on to a geodetic region and rendered in place using one or several layers.

5.1 From Dataset to Tile

Each layer corresponds to its own tile provider. A tile provider is able to initiate asynchronous calls to a tile data reader which in turn reads the image data from disk or from remote servers. Once the image data is ready, a tile can be created and pushed in to an in memory LRU cache so that the tile provider can return it upon request. If the tile is already in the cache, the tile provider simply needs to return it and update the cache upon request.

5.2 Chunk Rendering

6 Conclusion

1. Blabla; introduction in reverse
2. Future work:
    (a) Focus more on scientific rather than engineering goals

Length: About 1 page

Acknowledgments

The authors wish to thank A, B, C. This work was supported in part by a grant from XYZ.