PRo3D Rendering & 3D Analysis tool for instrument cooperation

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Purpose of (3D) Vision on Mars

- **Context**
  - What is interesting?
  - Where to go next?
- **Navigation**
  - Where am I?
  - Which path to take?
  - Am I moving correctly?
  - Any hazards?
- **Inspection**
  - Am I doing well?
- **Science….**
- **& Collaboration**
Targets of Rover Imaging: Customers / Functions / Products

- Mission Clients
  - Rover Driving Team to plan
  - Scientists to plan
  - Scientists to analyze

- The Public
  - For education
  - As tax payer
  - For science

- 3D Mapping
  - On-board path planning & hazard avoidance
  - On-ground for tactical & strategic planning

- Navigation
  - On-board visual odometry
  - On-ground absolute localization

- Visualization
  - Planning & understanding operations
  - Planning & understanding science
  - Context for instruments
- **PRoViP**: Batch Stereo / 3D Vision Processing
  - DTM, Panoramas, other 3D data products from PanCam/NavCam/LocCam

- **PRo3D**: Interactive Real-Time Rendering
  - Huge multi-scale 3D data
  - Support for scientific operations
Planetary 3D Vision – PRo3D Viewer

Planetary Robotics 3D Viewer (PRo3D) developed by JR long-term partner VRVis is an interactive real-time renderer to explore 3D vision products.

http://pro3d.space/
PRo3D Features I

- Interactive rendering of **multi-scale 3D surfaces** in different render modes (i.e. solid, wireframe)
- Efficient large-context navigation in the 3D scene using explore, free fly or orbital mode for overall scene understanding
- Ordered Point Cloud format* (OPC) containing 3D data as real Cartesian coordinates \((x/y/z)\) in different pre-processed resolutions to facilitate position and distance dependent level-of-detail rendering
- Visualization & navigation of **huge datasets** („no limits“ due to out-of-core technique)
- **Visual fusion** of multi-sensor and multi-scale data
- Visualization and manipulation of other data, such as **vrml objects, trajectories, 3D point lists** and sub-surface radar scans

*OPC format developed by VRVis & JR
PRo3D Features II

- handling of **multiple textures** and **maps** (DEM by-products) for 3D geometry complementation
- **measurement tools** for exact geological assessment of the surface
- **annotation** of surfaces and other scene elements
- **view planning** and **simulated view** functionality to simulate various instruments’ field of view
- **user interactive transformations** of all supported data types
- **multi user** handling / data exchange

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**Annotations of regions and features**

Color coded accuracy map visualization

MSL Mastcam 100mm, WBL planning scenario
Sol 981 – Sol 986, stereo base ~50m, distance to ROI ~170m
View planning foresees occlusion in cam view Sol 981

Geological annotations and measurements in MSL and MER-B data
Supporting Data Fusion and Levels of Detail
Interaction in PRo3D: Geological Annotations

Geometry

Style

Text

Projection

Derived Values
Work in Progress: Multiple Layers Data Structures & Rendering

- Multiple Textures
- Attribute Layer
• Geometric model & FoV / footprint of an instrument-carrying platform (e.g. rover)
  – WISDOM
  – Drill & CLUPI
  – ISEM, TSPP, ....
• Moving camera
• Generic interface
  – Allows defining mirror views as additional instrument option
• Platform geometry and instrument characteristics are defined in xml file
• Interface: C functions and structs (can be used with C++, C#, Python, ...)

InstrumentPlatforms.dll – PRo3D Robotic Interface
View Planner

- Simulate views
  - Cameras
  - Footprints of Instruments
- Bounding box projected onto Planet DTM / Ortho
- Dynamic / interactive display for planning
  - I/O of pointing angles

HIRISE super resolution texture:
Credits Tao & Muller, 2016
Can include CLUPI, ISEM, TSPP, ...
Global Wide Baseline View Planning & Verification on HiRISE DTM & ORI → Long Range Navigation DTM

WBS MSL Mastcam pair Sols 984-986 with 7m baselength (comparing real images and virtual renderings of HiRISE base map from the same position); distance to main portions of the scene about 170m
Inspiration / Complement for maintenance & display of observations & Landmarks:

NASA/JPL Operations Approach: ASTTRO Tool

3D HiRISE & Rover 3D Augmented Database

Geo-Located Images & Target Location Displayed
Measurements are data blobs in 3D overview

Clicking therein results in
- launch of custom presentation HMI
- Read-out & Display of Generic Instruments Data

Instrument data presentation within PRo3D: Initial simplistic view

Sol=44
SW Version=2.4.1
Shift Scientist=Frank
....
MINERVA Scheme

ExoMars Instruments' data:
- Footprints
- Frustum
- GUID / PDS Link
- Relevant resources
  - Images
  - Spectra (ISEM, [Ma_MISS], ..)
  - $\text{H}_2\text{O}\%$ (ADRON)
  - vtk file (WISDOM)
- Statistics
- Specific Instruments' analysis

Figure 6: MINERVA concept. The Instrument Teams (I1...I3) use the generic importer tools (or – in the case of vision – the existing vision processing results as available to JR) to ingest mission data into the 3D Observation Data Base. From there it is available to the 3D Visualization Engine with integrated GIS functionality, and the Non-spatial Data Analysis Platform. Different users can share the same locations, observations, and launch visual analysis of different instruments at a time.
PRo3D: Exploit object representation assets to represent Instruments‘ Observations‘ footprints
Visual Analytics: The Visplore Component

- Translating search patterns into DBMS I/F
- Direct use of meta & instrument data
- Cross references between data, meta data of different instruments
- Spatial & temporal relationship
- Finding new patterns in data
- …Users will find out
MINERVA in Operation

PRo3D - Stimson Site part of MSL data ingest

See https://www.youtube.com/watch?v=NTIS9OrlmTk
WISDOM Ground Penetrating Radar Fusion

Credits:
SAFER Team / WISDOM Team
WISDOM after correct alignment
Science Collaboration
Aspect: Virtual Reality

- E.g. RAVEN Idea by Aberystwyth University

Interactions on 3D Context & Instruments' data
- Joint annotations
- Joint Measurements

Multiple PRo3D instances running in parallel
Simulation by PRo3D (e.g. for training): Place Shatter Cones within „natural“ environment

- 3D Reconstruction of real (terrestrial) shatter cones
- Place them in real scene
- Check ability to find them at certain distance

![Image of shatter cones and simulation interface]
Positive identification challenging, but feasible.
Relevant Aspects not to forget…

- Updating SPICE Kernels & Instruments‘ calibration conditions
  - Versioning in 3D products / localization of instrument data

- Archiving OPCs
  - Not PDS4 – compatible

- Maintaining a unique 3D data base (cf JPL/ASTTRO)
  - Fusion of HiRISE DTM & Rover imagery
  - Mixture between engineering & science-driven products
  - Versioning, related to source data coming in, SPICE & calibration updates,….

- Access rights to data between international teams
  - Adding credentials to each data element?

- Tools‘ et al originators to be mentioned in publications (Digital watermarks…?)

- PSA Synergies? → 3D GIS Functionality / close-range & multi-scale capabilities / ….

- …. Many more aspects, requires workshop/s & training on their own
Derived Data Generation (secondary products):

PanCam Geological Analysis:
- Spectral feature extraction
- Spectral ratio maps
- Spectra extraction...

PanCam Visualisation:
- Rover and terrain
- Slope & resource highlights
- Colour vs. Illumination

*See ICD section 7 for a full list of primary and secondary data products.
PanCam tools
Get usable for entire mission
Validation started: MSL Data Processing Results & Visualization in Use by Scientists


Earth and Space Science

RESEARCH ARTICLE
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Special Section: Planetary Mapping: Methods, Tools for Scientific Analysis and Exploration

Key Points:
- Processing of Images from stereo cameras on Mars rover produces 3D Digital Outcrop Models (3DOMs) which are rendered and visualized in PRO3D.
- PRO3D enables efficient, real-time rendering and visualization of the 3DOMs, allowing extraction of large amounts of quantitative data.
- Methodologies for sedimentological and structural data analysis on PRO3D are presented at four locations along the MSL and MDR traverses.

Supporting Informations:
- Supporting Information S1
- Data Set S1
- Data Set S2
- Data Set S3
- Data Set S4
- Data Set S5
- Data Set S6
- Data Set S7
- Data Set S8
- Data Set S9
- Data Set S10
- Data Set S11
- Data Set S12

Abstract
Panoramic camera systems on robots exploring the surface of Mars are used to collect images of terrain and rock outcrops which they encounter along their traverse. Image mosaics from these cameras are essential in mapping the surface geology and selecting locations for analysis by other instruments on the rover’s payload. 2-D images do not truly portray the depth of field of features within an image, nor their 3-D geometry. This paper describes a new 3-D visualization software tool for geological analysis of Martian rover-derived Digital Outcrop Models created using photogrammetric processing of stereo-images using the Planetary Robotics Vision Processing tool developed for 3-D vision processing of ExoMars PanCam and Mars 2020 Mascam-Z data. Digital Outcrop Models are rendered in real time in the Planetary Robotics 3-D Viewer PRO3D, allowing scientists to roam outcrops as in a terrestrial field campaign. Digitization of point, line, and polyline features is used for measuring the physical dimensions of geological features and communicating interpretations. Dip and strike of bedding and fractures is measured by digitizing a polyline along the contact or fracture trace, through which a best fit plane is plotted. The attitude of this plane is calculated in the software. Here we apply these tools to analysis of sedimentary rock outcrops and quantification of the geometry of fracture systems encountered by the science teams of NASA’s Mars Exploration Rover Opportunity and Mars Science Laboratory rover Curiosity. We show the benefits PRO3D offers for visualization and collection of geological interpretations and analyses from rover-derived stereo images.

Barnes et al, 2018
On Panorama Viewing…

ExoFit Examples
Currently discussing: JR ImageVector Viewer (ImpactViewer): Panoramas & (multispectral) Images

Arbitrary layers: Distance, filters, …

Various analysis & edit modes, configurable

Distance

Azimuth

Elevation

Handlens

Color Values
MINERVA ROCC Embedding
(In discussion)

PanCam Team
ISEM Team
CLUPI Team
WISDOM Team
Ma_MISS Team
ADRON Team
MicrOmega-IR Team
RLS Team

MINERVA DBMS

Telemetry
PDS4 Weekly Sync TBD

DAR

PDS4
A-SDP
3D-ROCS

2D GIS

PRO 3D
PSA (Option)

Telemetry

DAR

PDS4

MINERVA Queries

Display & Select

Retrieve

Science Community