Desktop Exploration of Remote Terrain (DERT)

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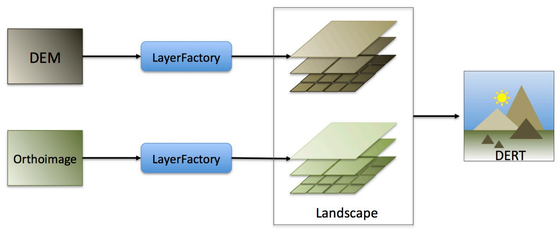
A digital terrain model (DTM) is generally thought of as a height map or digital elevation model (DEM) draped with one or more co-registered orthoimages or layers. NASA missions have produced numerous DTMs for locations on Earth, Mars, and the Moon using terrain reconstruction techniques with data from orbiters and other remote sensors. When explored in 3D, these data sets can provide a unique perspective of the subject terrain and take advantage of computational features not available in a 2D setting. However, typically large and complex, they are somewhat underutilized due to the lack of dedicated software and documentation.

The goal of DERT is to provide a freely available software tool for exploring NASA DTMs in 3D on the desktop . With this in mind, DERT offers 3D terrain visualization and navigation, time realistic simulated lighting and shadows, rendering of multiple co-registered image layers, and several tools that aid in understanding the topography and spatial relationships of terrain features. It is open source and available for download for Mac and Linux platforms at https://github.com/nasa/dert.

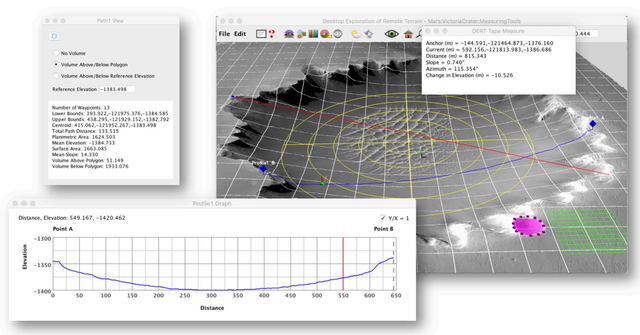
Terrain Visualization: The purpose of DERT is to visualize the results of NASA terrain reconstruction efforts while remaining interactive and responsive to measurement and other data queries. Toward this end, it employs a virtual world implemented with a scene graph and OpenGL. A surface mesh, created from the DEM, is draped with textures created from selected orthoimages.

DERT attempts to maintain a balance between visual capabilities and performance while at the same time handling very large terrain data sets. To achieve this, it maintains the virtual world in small parts, some with varying levels of detail. For example, the terrain structure is based on a multi-resolution tiled image pyramid, mandating that only enough data for the required level of detail is loaded and rendered. This approach was chosen over other terrain rendering techniques (clipmaps, for example) because it retains access to actual data, facilitates very large file sizes, preserves interaction responsiveness during collision detection and does not require a high level shader language.

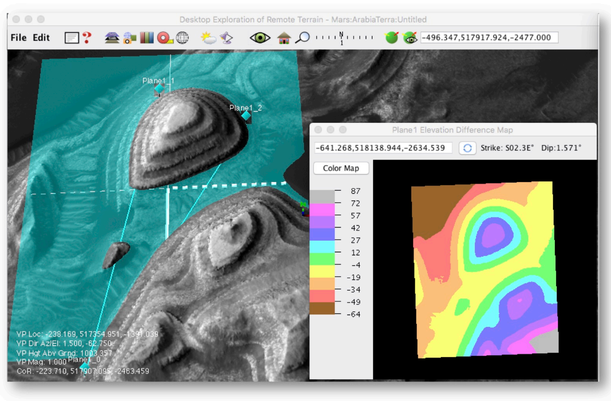
Data Preparation: A companion application called *LayerFactory* converts each DTM layer into an image pyramid. DTM file formats include PDS and GeoTIFF, both supported by widely available GIS tools. Image pyramid tiles are written as PNG format using lossless compression. LayerFactory does not modify the data except for generating lower resolution files for the pyramid by averaging the original file. Otherwise, scale and color remain true. Together, all of the layers constitute a *Landscape*. The DERT website provides examples of creating landscapes using data from a number of sources including MRO, LRO, Mars Express, SRTM, and Landsat.

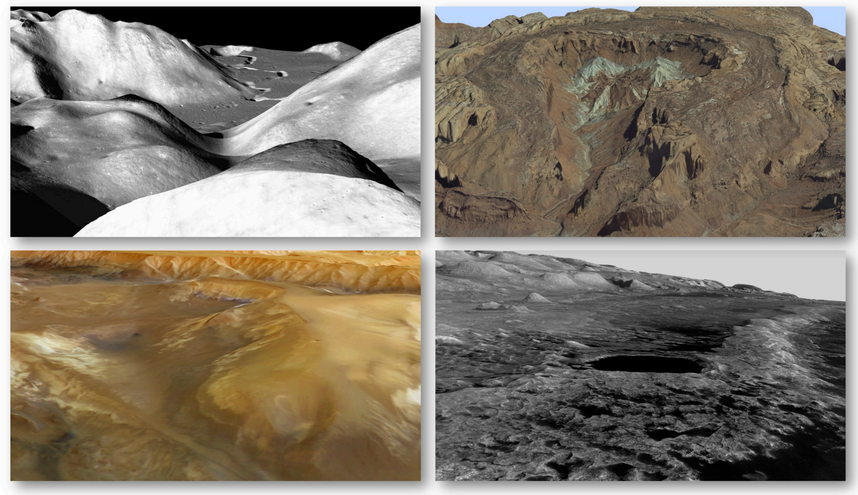


Measurement: DERT provides several interactive methods for measuring the landscape. The Tape Measure tool performs a point to point measurement of distance, elevation change, slope, and bearing. The Profile tool graphs a profile of the terrain along a transect. The Path tool estimates distance along a path and surface area and volume for an enclosed polygon. Three types of grids are available as well. Below are a variety of tools displayed with Victoria Crater including a radial grid (yellow), Cartesian grid (green), a path (magenta), a profile (blue), and the tape measure (red). The location of the red line in the profile graph is matched by the green marble in the crater. A white surface grid drapes the entire DTM.



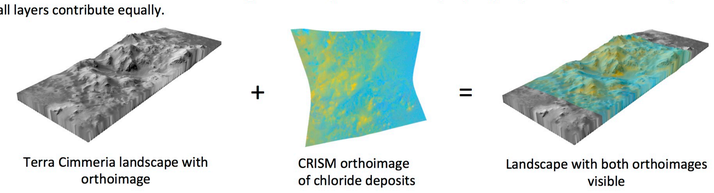
Plane: This special tool provides an interactive cutting plane with an optional map of elevation difference from the plane to the underlying terrain. The plane is defined by 3 points that can be manipulated to align with terrain features such as strata. The plane also reports strike and dip values.



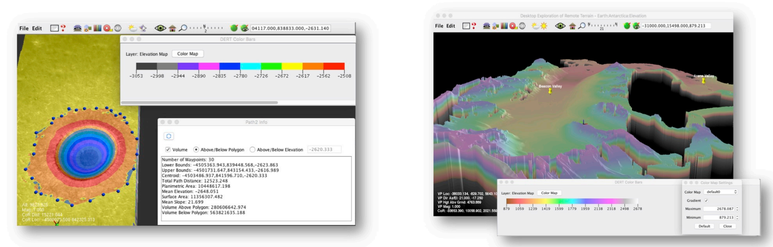


Landscapes viewed in DERT. Upper left: Apollo 15 Landing Site (LRO LROC), Upper right: Upheaval Dome, Utah (USGS), Bottom left: Hebes Chasma (Mars Express HRSC), Bottom right: MSL Landing Site (MRO CTX, HiRISE)

Layers: DERT permits 7 different co-registered layers to be draped on the terrain surface simultaneously. These layers include orthoimages, color mapped elevation derivatives, color mapped ortho-fields, and camera footprints and viewsheds. Elevation derivatives include elevation, slope, and aspect. Ortho-fields are single component images that require a color map to visualize. Color maps are loaded from customizable text files and their ranges can be adjusted interactively. Opacity may be adjusted for each layer or distributed so that all layers contribute equally.

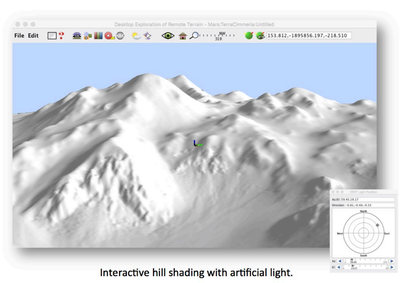


Terra Cimmeria landscape with orthoimage CRISM orthoimage of chloride deposits Landscape with both orthoimages visible

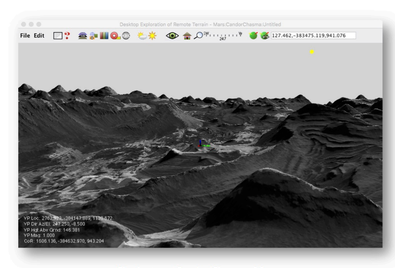


Left: Elevation contours are used to help identify the location of path waypoints. Right: Color contours for a region of Antarctica near McMurdo Sound shown with the gradient option.

Lighting and Shadows: DERT simulates two types of interactive lights: solar and artificial. The artificial light is controlled by changing its elevation and azimuth directly whereas the solar light is controlled by time. JPL's SPICE library is used to determine the position of the Sun relative to the landscape. The solar option provides realistic lighting and shadows whereas the artificial light provides the user with complete interactive control of lighting aspects for tasks such as hill shading. Shadow rendering is implemented with a shadow map technique. The resolution of the shadow map is configured by entering the center and radius of the region to be shadowed.



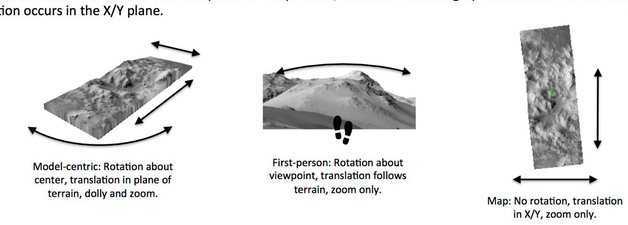
Interactive hill shading with artificial light.



Shadows on Candor Chasma, Mars.

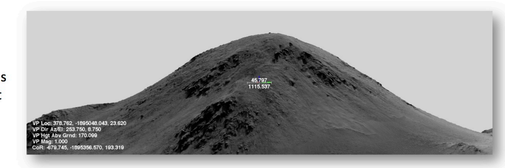
Navigation: DERT uses the ENU coordinate system where the +X axis represents East, +Y axis is North, and +Z axis is up. Navigation is performed by moving the viewpoint with the mouse including translation along the terrain, pan and tilt rotation around a center point, dolly to and from the center point, and viewpoint camera zoom. An overlay lists navigational field values and a compass provides the current bearing of the viewpoint. Tilt is constrained to a maximum of 180 degrees to avoid disorientation and a home button returns the viewpoint to the default overhead position. In addition to mouse navigation, a user may "seek" an object, moving the viewpoint to that object's vicinity.

There are three different navigational modes: model-centric, first-person, and map. Model-centric (the default) translates along the plane of the terrain and rotates about a point at the center of the screen. Where this mode manipulates the landscape from above, first-person puts the user on the terrain surface. Translation in this mode follows the terrain surface and rotation is around the viewpoint. In map mode, the view is orthographic. Rotation is not allowed and translation occurs in the X/Y plane.

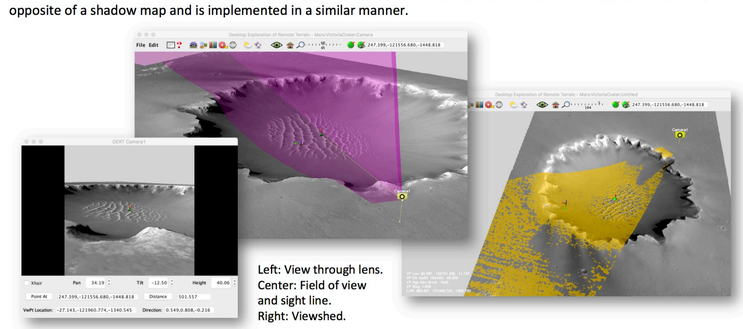


Model-centric: Rotation about center, translation in plane of terrain, dolly and zoom. First-person: Rotation about viewpoint, translation follows terrain, zoom only. Map: No rotation, translation in X/Y, zoom only.

Right: An overlay displays navigational fields as well as the distance to and scale at the center point.



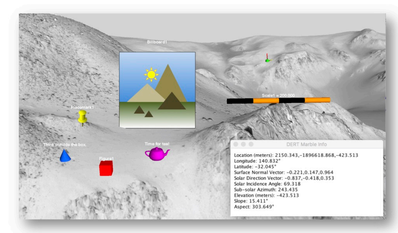
Camera: This map element simulates a camera placed at a location in the landscape and provides a separate view of the terrain as would be seen through its lens. The camera can be raised, panned, and tilted. Point the camera at a specified location and obtain the distance to that point. The camera footprint or viewshed may be displayed as a layer. The viewshed is the part of the footprint that is not obscured and will appear in a camera image. It is basically the opposite of a shadow map and is implemented in a similar manner.



Left: View through lens.
Center: Field of view and sight line.
Right: Viewshed.

Landmarks: Landmark map elements including Placemarks, Figures, and Billboards provide options for annotating the landscape and can be added with a single click at the desired location. For visibility, each will auto-scale as the viewpoint changes. A placemark represents a location with a 2D icon of either a pushpin or a flag. A figure is a 3D object that has depth and will cast shadows. A billboard positions a user-provided image in the landscape. The placemark and billboard landmarks always face the viewpoint. The green marble is a special landmark that appears at the last location of a mouse single-click in the terrain. Information about that location is provided in a separate window.

The Scale Bar map element provides a 3D map scale object. It does not auto-scale with the viewpoint but can be given a custom size and orientation. When dragged with the mouse, all map elements follow the terrain. This feature provides 3D movement with a familiar 2D interface and reduced user disorientation.



Left: Some examples of map elements including a pushpin placemark, three figures (cone, box, and teapot), a billboard, and a scale bar. The green marble is in the background.

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