WORLD-WIDE-WEB TOOLS FOR LOCATING PLANETARY IMAGES

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The explosive growth of the World-Wide Web (WWW) in the past year has made it feasible to provide interactive graphical tools to assist scientists in locating planetary images. The highest available resolution images of any site of interest can be quickly found on a map or plot, and, if online, displayed immediately on nearly any computer equipped with a color screen, an Internet connection, and any of the free WWW browsers. The same tools may also be of interest to educators, students, and the general public. Image-finding tools have been implemented covering most of the solar system: Earth, Mars, and the moons and planets imaged by Voyager. The Mars image-finder, which plots the footprints of all the high-resolution Viking Orbiter images and can be used to display any that are available online, also contains a complete scrollable atlas and hypertext gazetteer to help locating areas. The Earth image-finder is linked to thousands of Shuttle images stored at NASA/JSC, and displays them as red dots on a globe. The Voyager image-finder plots images as dots, by longitude and apparent target size, linked to online images. The locator (URL) for the top-level page is `http://ic-www.arc.nasa.gov/ic/projects/bayes-group/Atlas/`.

Through the efforts of the Planetary Data System and other organizations, hundreds of thousands of planetary images are now available on CD-ROM, and many of these have been made available on the WWW.* However, locating images of a desired site is still problematic, in practice. For example, many scientists studying Mars use digital image maps, which are one third the resolution of Viking Orbiter survey images [1]. When they do use Viking Orbiter images, they often work with photographically printed hardcopies, which lack the flexibility of digital images: magnification, contrast stretching, and other basic image-processing techniques offered by off-the-shelf software. From the perspective of someone working on an experimental image processing technique for super-resolution [2], the discovery that potential users are often not using the highest resolution already available, nor using conventional image processing techniques, was surprising. This motivated the present work.

▷ The Mars Atlas displays USGS [3] map tiles, reprojected so that they fit together almost seamlessly in some browsers and can be scrolled in any compass direction in 5° steps. Locations may be either be selected from a list of feature names or picked by pointing and clicking at a a global map of Mars to zoom in on a $15^\circ \times 15^\circ$ area. The global map is currently a simple cylindrical projection at 1/2 degree/pixel, and the closeup is currently at 1/16 degree/pixel. After locating a desired area, centered on a $5^\circ \times 5^\circ$ tile, the user can either display the original 1/256 degree/pixel digital image map for that tile, or view a Viking Orbiter coverage map. The coverage map shows image footprints as colored outlines superimposed against the map, at a scale chosen based on how many overlapping outlines cover the area. This information was previously available only on printed coverage maps, or in text form by querying the IRPS database [4], from which the present graphical maps were derived. An additional mouse click displays a thumbnail rendition of the raw image, and another displays the full image, if it is one of the online CD-ROMs[1].* In addition to the comprehensive coverage, special sections have been prepared manually to show detailed information on the Mars Pathfinder landing site and on Gusev crater.

▷ The Earth image-finder displays a blue and green globe, with a red dot for each shuttle image. Clicking on the globe rotates it if necessary and displays a $10^\circ \times 10^\circ$ closeup below. Clicking near a red dot on the closeup displays the corresponding image from NASA/JSC [5]. The locations are read from a textual table on the WWW, which was previously the only interface available. Pages for each new mission are generated by an automatic process, which in principle could even start up automatically when new images are put online. The fact that the globe the user clicks upon, and the image that appears in response, are physically located at two geographically remote NASA centers poses no technical problem whatsoever on the WWW. This suggests the idea that datasets from different missions/instruments to the same planetary target can easily be presented as a unified whole even if they reside at different institutions.

▷ The Voyager image-finder currently displays a "geo"-centric longitudinal view of the positions of images taken during the Voyager encounter of each moon and planet, making it easy to find the highest resolution image of any desired part of the target. The distance from the center indicates how big, in pixels, the moon or planet will appear, and the position around the circle indicates how the target is rotated on its axis. Pointing and clicking lists parameters of images in the selected sector, together with links to the browse and full-scale images on CD-ROM [6],* so that one more click displays the image. Possible enhancements for the future include a clickable histogram for other image parameters like latitude and phase angle, and perhaps even a turnable globe made from images taken at different longitudes.

▷ Ideally, all images of the entire explored solar system would be accessible from one starting point, or at least all the images available online. This goal has nearly been achieved, except for Mercury and the small bodies. There is already a browser for Magellan images provided by the PDS Microwave Subnode [7], though it may be worthwhile adding a map or globe front-end to it. The Clementine project recently created a lunar image browser [8]. Depending on what capabilities are added to that, it may be unnecessary to do more than provide a link to it.

The approach taken so far has been to pre-generate all of the images and hypertext files, using Lisp code running on a Symbolics Lisp Machine. The result is portable to different types of servers and efficient to access, but has limited flexibility: with a large but finite amount of disk space, it is not practical to offer high resolution map projections or a selection of overlays, and the edges of maps always fall on a 5° boundary. An alternative approach which may be attempted in the future is to have a program on a server generate maps at any scale on demand, reading the appropriate map tiles from CD-ROM as needed. The dataset [3] is well designed to support this. This is similar to the interactive approach taken with the (Earth) map viewer at Xerox PARC [9], though that produces only line drawings, which are less computationally expensive. Another direction for future work is false-color visualizations of planetary surface data other than images, e.g. data from the Viking IRTM instrument.

Any WWW-based tool, being limited by network bandwidth and latency and lacking incremental redisplay capability, will not match the performance of local software on the user's machine. However, a tool delivered on the WWW has the advantage of being immediately available on a wide variety of types of computers, and does not require the user to buy a jukebox for all the CD-ROMs.

These tools also serve the purposes of public outreach and educational resources. More than 12,000 different machines (and presumably about the same number of users) accessed the Mars Atlas in its first six months. Most never went past the first page; presumably many of those followed the links provided there to excellent colorful collections of Mars images that others have compiled, and never returned. Still, despite the links to more general collections, over four thousand users went to the global map and zoomed in, usually choosing the most prominent features. Less than one in ten tried looking up features by name or locating raw Viking images, a service that is aimed more at science users. Clearly there is public interest in Mars for entertainment and education. The Mars Atlas is also being adapted for use as part of an educational CD-ROM for high school science classrooms [10].

Possible scientific uses of this and similar WWW tools include:

- locating raw images for analysis or processing (e.g., super-resolution [2]),
- relating images to data obtained from other instruments,
- as a prototype, testing ideas for data distribution from new missions (the Shuttle image-finder can be viewed as an example of this),
- allowing future online scientific papers to include hypermedia links to the map area (or image) under discussion. Of course, online hypermedia papers also have the potential for including their own figures and photos.

References

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* The Mars Atlas benefits greatly from the existence of two online collections of raw images. It incorporates 1/8-scale images created by M. Caplinger of MSSS, and is linked to a publically accessible FTP collection of CD-ROMs provided by P. Yee of Ames.