Clementine Stereo Data Analysis: Digital Terrain Models and Rectified Color Images;
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Introduction. Three dimensional morphology may be used to understand the role of lunar surface dynamic processes. Color and photometric imagery can reveal the chemical, mineralogical, and physical properties of the the lunar soil. Insights into geological stratigraphy and material depositional history may be gained by studying the variation of color and/or photometric properties of the surface with topography. Here we describe two approaches of producing digital terrain models (DTMs) using automatically matched stereo Clementine imagery: (1) an initial, but fast, method that relies upon using approximate camera positions and orientation data, for producing relative height DTMs. (2) a more accurate technique of photogrammetric bundle-block adjustment using ground points for producing absolute height DTMs. It is important to incorporate a DTM into the image rectification process when producing ortho images, else topography may cause localized spatial distortions. Although this effect on Clementine nadir colour imagery is small, it should be taken into account for photometric imaging sequences taken at different viewing angles where surface normals and shading effects are of interest. Color ortho image mosaics and DTMs produced from Clementine imagery are presented and analyzed.

Data. Clementine obtained just under 2 million multi-spectral images from lunar orbit [1], Whilst the majority of the data were collected with the cameras pointing towards the nadir, and this resulted in very weak stereo inside image overlap regions, the spacecraft was sometimes tilted to obtain image pairs with a much stronger stereo effect. Good stereo coverage was obtained in polar regions at latitudes above 60°, and in some localized areas elsewhere towards the end of the lunar mapping sequences. We analyzed in particular two UV-VIS camera stereo image sequences, one near Mare Orientale (88°W-86°W, 15°S-22°S), and the other of the crater Kepler.

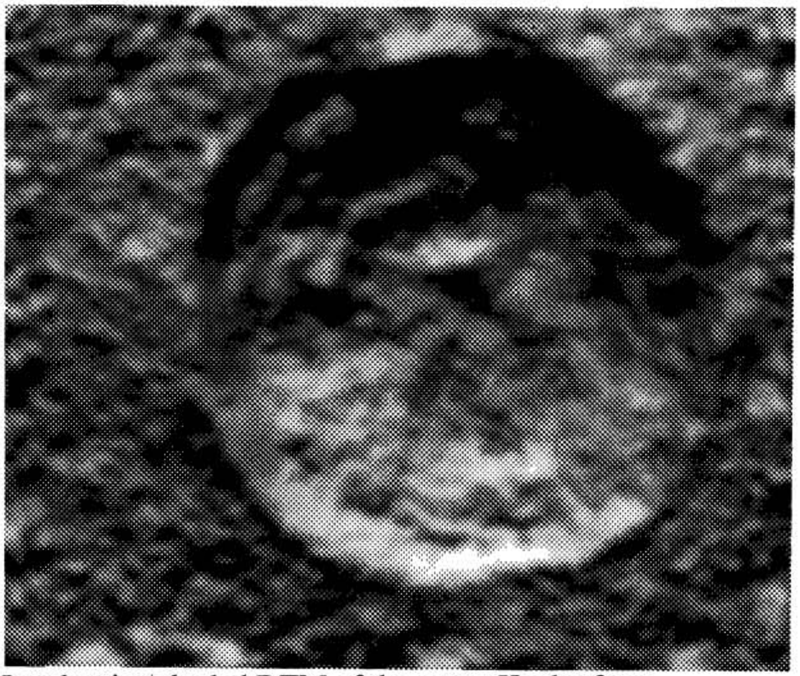
Method. First, overlapping images are identified with good stereo parallax, and these are then matched using the UCL "Gotcha" (Gruen-Otto-Chau algorithm) semi-automated stereo matching program [2][3]. Stereo intersection of light rays at the Moon´s surface between matched image points in both camera systems are determined and converted into longitudes, latitudes, and heights. These data are then interpolated to produce a DTM. Finally, images can be rectified on the basis of this terrain model, reprojected into a map projection, and then combined to form colour mosaics.

The process of stereo intersection relies upon knowledge of camera positions and orientations. Two approaches are used to determine these:

(1) Approximate approach: The camera positions and orientation data as computed from the best available SPICE kernels are used. The DTMs produced are relative only, due to offsets in longitude, latitude and height caused by errors in the SPICE kernels. As many stereo pair combinations overlap, it is possible to estimate spatial and height offsets between each individual DTM. A mean is selected and a correction for offsets is applied to each of the original matched points before generating a combined DTM. Errors are estimated for height and position offsets.

(2) Rigorous approach: A large numbers of ground points on the images are selected. Latitudes, longitudes and heights of these points are then calculated in a "bundle block adjustment" program, "CLIC", from TUM [4]. In this procedure spacecraft trajectory and camera pointing are determined along with the spacecraft coordinates. This procedure allows us to achieve precise registrations of color filter images.

Results. Utilizing the methods described above, it is possible to derive regional control point networks, DTMs and geometrically corrected color images of the crater Kepler and the Mare Orientale stereo image sequences from Clementine. Interpretation of the spectral information and topography data will be given at the time of the conference. Presence of photometric effects in the images due to varying surface slopes [5] and their possible correction will be discussed.



Lambertian shaded DTM of the crater Kepler from Clementine imagery on orbit 314 - artificial illumination from the North (DLR/UCL).

References:
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