MERCATOR - AUTONOMOUS NAVIGATION USING PANORAMAS.

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Introduction: Mercator is a project that is evaluating the ability of autonomous navigation using horizon matching of panoramas. Other work has been done looking at autofocus navigation using different techniques [1,2,3,4]. A similar project was conducted [5], but was not done at the same level of detail as this one.

We have conducted tests of data from the Moon with synthetic data and a full real-world test on the Earth with good results. There are two steps to implement this system.

First, it requires a high resolution topographic model of the navigation area. From this topographic model, we construct syndetic panoramas at regular intervals, ultimately at the resolution of the terrain model, Fig. 1.

Second, it requires an actual panorama from a location in the area. We would trace the horizon line of this panorama and do a search through the precomputed database of synthetic panoramas to find the closest match as described in [7].

Real World Test: We have conducted a real world test in a site in southern Arizona. Initial results were presented previously [6, 7], and this work focused on more robust testing and higher resolutions.

We generated a topographic model of the testing area using stereophotoclinometry [8, 9]. Its resolution is 1.5 meters in a region 4km x 4km. We generated synthetic panoramas every two meters.

Next, we took real data from the test site as described in [7]. The test site was processed by hand due to clouds. Ultimately, this would be done automatically by on-board computer systems.

Stitching) We used eight or nine images to stich together a panorama using Itagui software. We set the control points manually basing them on features on the horizon to control for distortion, Fig. 2.

Rotation) We shifted the image so north was in the middle of the image.

Cloud removal) We removed, using Photoshop, the sky, clouds and leafless branches to generate a panorama that the horizon tracing program could use, Fig. 3. Obviously, this step would not be required for operations on the Moon and most other objects.

Horizon Trace) We created a routine to read tiff images and identify the horizon, Fig. 4.

Tilt) For each panorama, we removed the camera tilt. Although the camera was on a tripod, we did not have sufficient instrumentation to reduce tilt to less than one degree.

Horizon Matching: Once the panoramas where converted into a horizon trace, Fig. 4, we compared them to the recomputed synthetic horizons. The first step was to test over the entire 4km x 4km region. That provided us a map of the quality of match over the region, Fig. 5.

Because the test is has a wide (10 meter) sampling, we needed to ensure we were detecting the global minima rather than a local minima. We determined boundaries of regions of excellent matches. We identified between three and eight different unconnected regions. We did a second comparison test for each of these regions at the 2 meter resolution, Fig. 6.

Results: We ran 12 tests through our system and determined the location of all of them to a high level of accuracy, typically within 20 meters. The search for global minima improve the matched location for four locations. We will report the details of these tests, their error and possible improvements.

References:

[1] Li R. et al (2002) *JGR*, 107, E11. [2] Olson C. F. and Matthias L. H. (1998) *Intern. Conf. on Robotics & Automation.* [3] Li R. et al. (2004) *Photogramm. Eng. Remote Sens.,* 70(1), 77-90. [4] Li R. et al. (2011) *JGR*, 116, E00F16. [5] Cozman F. et al. (2000) *J. Autonomous Robots*, 9, 135-150. [6] Palmer E. E. et al. (2012) *LPS XLIII*, Abstract #1659. [7] Palmer E. E. et al. (2013) *LPS XLIV*, Abstract #2650. [8] Gaskell R. W. (2008) *LPS XXXIX*, Abstract #1152. [9] Gaskell R. W. et al. (2008) *MAPS*, 43, 1049-1061.

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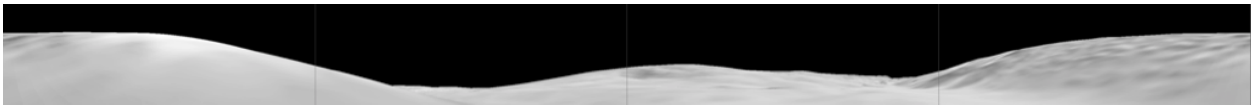

Figure 1 – Synthetic panorama

Figure 2 – Real panorama. Rotation is required so that north is in the center.

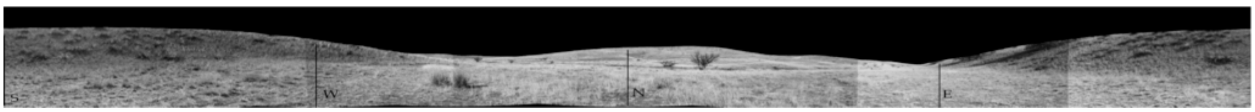

Figure 3 – Real panorama with sky removed.

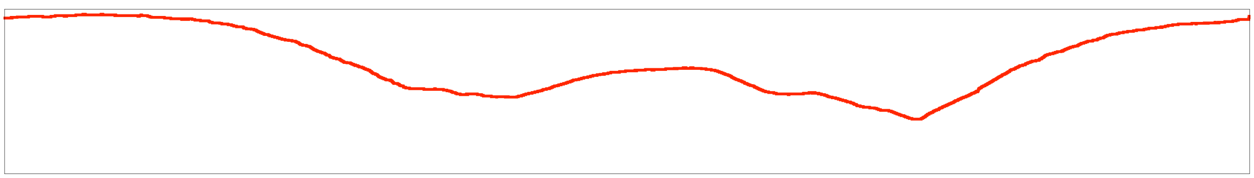

Figure 4 – The trace of the horizon.

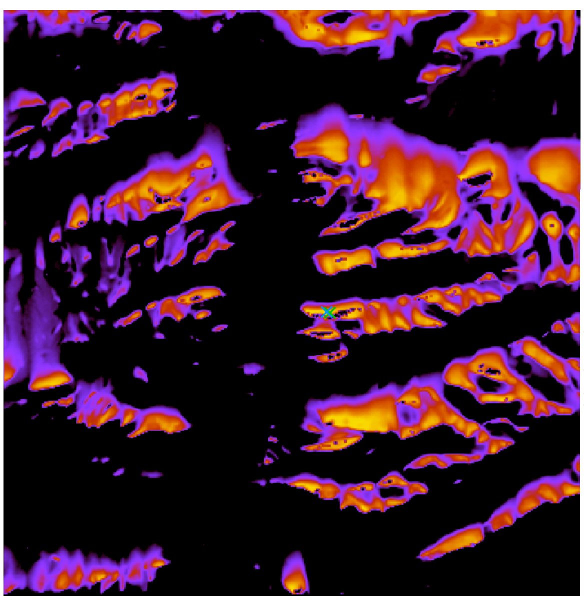

Figure 5 – A map of where the best fits are

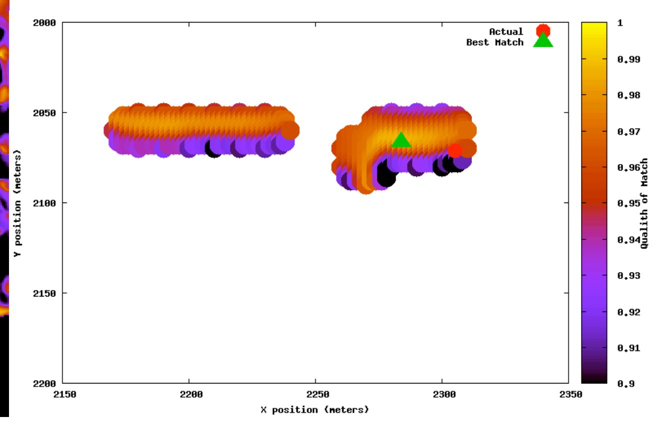

Figure 6 – High resolution results