AUTOMATED IMAGE MATCHING TECHNIQUES FOR PLANETARY PHOTOGRAMMETRIC MAPPING. R. A. Saleh and R. L. Kirk, Astrogeology Science Center, U. S. Geological Survey, 2255 N. Gemini Drive, Flagstaff, AZ 86001, USA, rsaleh@usgs.gov.

Introduction: Image matching techniques are a key component of several of the most critical tasks in photogrammetric mapping. While significant successes have been achieved in automating matching techniques for Earth-based photogrammetric mapping, there still exists a need to introduce the best of these methods into planetary cartographic production. These matching techniques can be classified into several categories. These include area-based, such as cross-correlation and least squares methods (LSM); feature based methods, such as SIFT and SURF; and statistical measures, such as Mutual Information (MI). While these methods are applied in the spatial domain, others can be appplied in the frequency domain , such as Fourier transformation. Another category includes context based methods. Some of these techniques have been investigated since the early '50s with the goal to achieve a high level of automation of mapping tasks that would otherwise incur costly manual labor. While significant successes have been achieved in automating production-viable photogrammetric systems, industrial vision systems, and medical imaging systems, no similar successes can be claimed in the planetary domain. In the case of the operational planetary image analysis toolset, ISIS [1][1], there are specific embedded routines and stand-alone functions for point matching, such as *pointreg* and *coreg*. These routines and functions are fundamental to production of high precision cartographic products. Reliable image registration is necessary for image data fusion and for mapping from large data sets by reducing the amount of human interaction required controlling them. Even with these existing tools, however, the current level of manual validation and editing of data is quickly making global control products of modern missions a practical impossibility. For example, the Lunar Mapping and Modeling Project [2, 3] funded the production of enormous controlled polar mosaics from Lunar Reconnaissance Orbiter Camera (LROC) [4, 5] images. These mosaics included over 7,500 images – and required hundreds of hours of labor yet they will use only 2% of the total LROC NAC image dataset. Uncontrolled data are generally sufficient for qualitative investigations, but generally insufficient for spatial and geometric analyses or for fusion with other data sets. Several different groups have strongly recommended that all planetary datasets be controlled [6, 7].

Curent Status: The underlying matching technique currently used in ISIS functions is the cross-correlation method. The software has been designed to facilitate the "plug in" of other available techniques, such as least squares method, frequency based, or MI, but these are not yet supported operationally. In cross-correlation matching, the difference between the image patches is modeled as linear functions of the intensity values combined with two-dimensional integer shift. This shift is typically one pixel at the search direction line, and once exhausted, the search shift to the next line in the search direction. As it currently stands, matching in ISIS does not model geometric and radiometric differences, except crudely at the level of the whole matching patch. These differences affect success, efficiency and accuracy of matching; hence geometric rectification and radiometric filtering can be applied to partially compensate for these differences. The outcome requires substantial manual editing of the list of candidate matches to eliminate blunders, which is very costly in comparison to the previous automated matching step. As the size and complexity of image datasets increase due to the number of different imaging systems, different illumination conditions, etc., the amount of manual editing required will make controlling these image datasets cost prohibitive.

Proposed work: In this abstract, we describe a project that aims at developing new and improving existing matching techniques for tiepoint and groundpoint measurement functions. These functions will support high accuracy, high efficiency production of geodetically controlled planetary mapping deliverables. The initially proposed development would be carried out in three phases, each focusing on a different aspect of the automated matching problem. While we describe all three phases here, we are currently focusing on the first phase only. We intend to make a better use of area-based matching algorithms already available in ISIS, with the primary goal of eliminating "false positives," i.e., matches that pass simple statistical tests and thus appear valid to the software but are incorrect. Figure 1 shows correct match, false positive, and failure to match conditions. In the top row, the right image shows both a false positive matched in ISIS program called *qnet* along with the correct location next to it. The middle row shows a failure to match. The yellow circle shows the location where a successful match would have been found. In both cases, the illumination of the two Lunar Reconnaissance Orbiter Camera (LROC) images being compared is incompatible, so it is not obvious why the outcome was a false positive in one case and a failure in the other. The bottom row shows an example of a false positive on Mars (THEMIS IR [8]) images with inconsistent illumination.

[1] ISIS: The Integrated Software for Imagers and Spectrometers

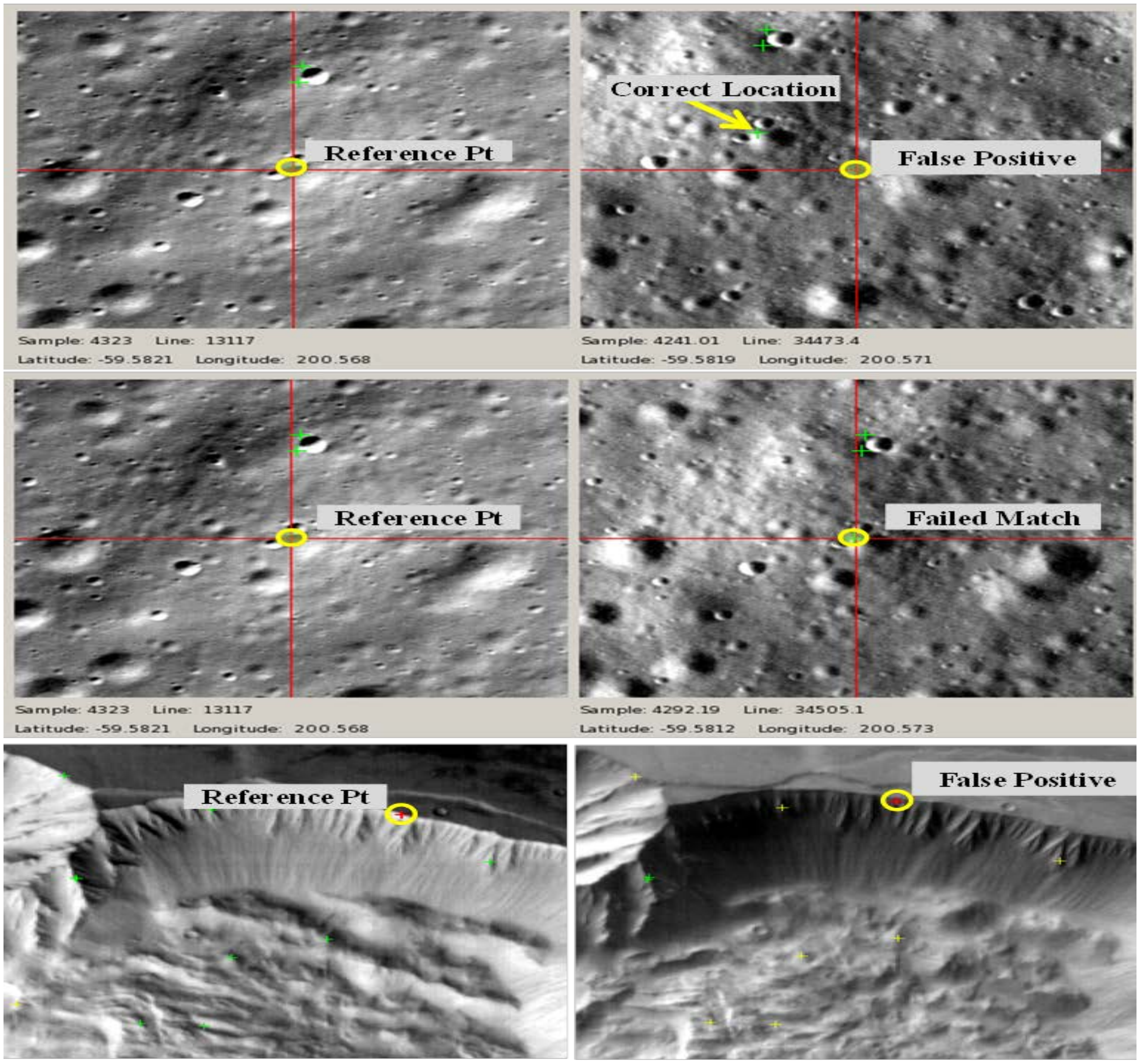

Figure 1. Examples of three possible Matching results from ISIS "qnet" program The rows show correct match, two false positive conditions, and a failure to match

In this project, the reduction or even elimination of the false positive cases will be realized by optimizing the low-level algorithm for least squares matching methods, adaptive filtering of the images, improved resampling techniques to minimize perspective distortions between patches being matched, quasi-epipolar searching, forward and backward matching, and outlier detection.

The second phase will involve the introduction of more advanced matching techniques such as advanced least squares matching, Fourier domain correlation and matching based on Mutual Information (MI), as well as combinations of these methods. The third phase would include the introduction of even more advanced and robust matching approaches based on identifying and matching features such as points, lines, areas, and even complex constructs such as impact craters.

Conclusion: Image matching accuracy, matching success, and false positives are all affected by image quality issues such as differing image geometry, varying radiometric quality, differences in spectral responsivity, and especially the need to match radically different image types such as visible, infrared, and radar data. Our proposed work will address these difficulties in multiple ways (such as enhancing current ISIS functions, adding limited improvements, and introducing advanced techniques) to produce efficient and accurate matches.

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