MANUAL SURFACE FEATURE CLASSIFICATION AND ERROR ANALYSIS FOR NASA'S OSIRIS-REx ASTEROID SAMPLE RETURN MISSION USING QGIS.

M. M. Westermann[1] [1]University of Arizona OSIRIS-REx (mmwest@orex.lpl.arizon.edu)

Introduction: Error mitigation of manual detection and classification of rocks, boulders, and craters on image mosaics can be accomplished through the use of open source geographic information systems (GIS) and standard land-cover change analysis methods. More accurate detection and classification of rocks, boulders, and craters, hereafter referred to as hazardous features, is especially important for NASA's OSIRS-REx Asteroid Sample Return Mission with target asteroid (101955) Bennu. OSIRIS-REx is the first US lead space mission that will return a pristine sample of carbonaceous asteroid to Earth in 2023, providing unprecedented insight into the history of our Solar System. A unique syndicate of engineering and science during proximity operations around Bennu is required to successfully navigate, select a sample site, and ultimately perform a Touch-and-Go (TAG) maneuver, where the spacecraft's articulating arm or TAG Sample Acquisition Mechanism (TAGSAM) will extend to barely touch the surface and extract a minimum 60g regolith sample from Bennu [1]. TAGSAM can only accommodate a grain size of <2cm and a sampling surface angle of <14˚. As rocks, boulders, craters, and other large surface features threaten these criterion, accurate identification and classification is a vital input to inform sample site selection.

Accurate manual detection and classification of hazardous features is jeopardized by human discretion. To mitigate human-error it is necessary to classify the same surface region multiple times or by multiple users and have the ability to compare the datasets. Land-cover change analysis methods like cross-classification are commonly used with remotely sensed data of Earth to observe how land types change on a temporal scale. In this study, the open source geographic information system (GIS) Quantum GIS (QGIS) was used to perform a cross-classification analysis to compare two hazardous feature datasets of the same region on a local test image mosaic of Bennu.

Methods: A local image mosaic of Bennu's surface was computer-generated by the OSIRIS-REx Image Processing Working Group (IPWG) to use as the basemap layer for digitizing (figure 1). Using the QGIS shapefile layer capability, rock, boulder, and crater polygon layers were created and in edit mode the contours of hazardous features were manually digitized resulting in three separate shapefiles with feature classification type indicated in the attribute table. The three shapefiles were merged into one shapefile using the vector layer data management tool. A field, called rast_value, was added to the shapefile that assigned a numeric value that distinctively corresponded to either rock, bolder, or crater. The shapefile was then rasterized using the same resolution as the basemap layer and based on the rast_value column ultimately resulting in a raster where the pixel value indicated the hazardous feature type. This process was repeated once more on the same image mosaic, however instead of digitizing exact contours around the hazardous features, more generic polygons were drawn so that it would obviously vary from the first dataset. The process ultimately resulted in two unique hazardous feature shapefile datasets and two unique hazardous feature rasters where the first shapefile dataset and raster are called shapefile1 and raster1 and the second shapefile dataset and raster are called shapefile2 and raster2 (figure 2).

Figure 1: Local test image mosaic of Bennu used as the basemap for digitizing hazardous features.

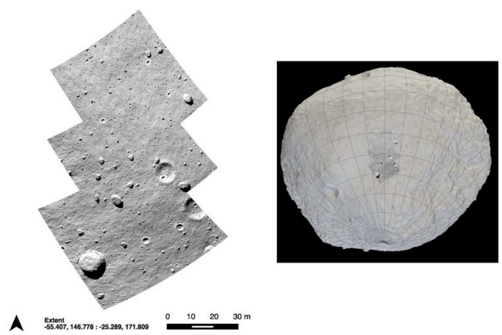
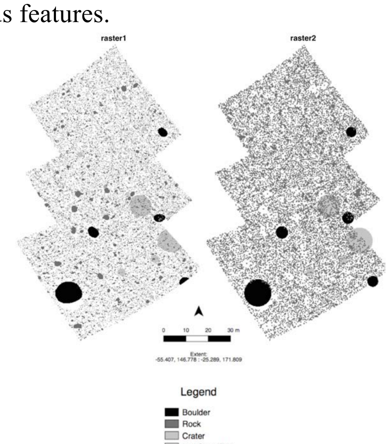


Figure 2: Raserization of shapefile1 and shapefile2 hazerdous features.



Using raster1 and raster2 as inputs, within QGIS the Cross-Classification and Tabulation plugin tool from SAGA geoalgorithms was run to produce a cross-classification error matrix table and cross-classification raster grid. From the cross-classification error matrix the omission error, commission error, and over-all accuracy were calculated (figure 3). The cross-classification raster grid was colorized to visually represent how the classified pixels of the input rasters converged or diverged from each other (figure 4).

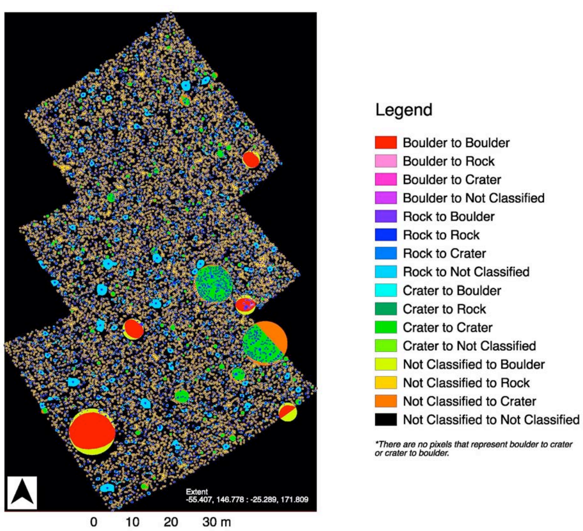
Discussion: The cross-classification analysis produced valuable quantitative and visual results for exposing differences and similarities between two datasets that are meant to define the same hazardous features. Though the datasets created for the purpose of this study were intentionally generated to be obviously distinct from one another, the same cross-classification technique could be used on datasets with more subtle differences. Overall accuracy is likely the most obviously useful result, providing the ratio of total pixels classified with the same value between raster1 and raster2 to the total number of pixels in the basemap. This ratio is useful to get a quick understanding of whether datasets are reliable enough to inform site-selection. This study yielded an overall accuracy of 80.41%, meaning 80.41% of pixels in the basemap were classified the same way in raster1 and in raster2. Omission error and commission error elaborate on overall-accuracy. Omission error yields the probability of a pixel in raster2 having the same value as the same pixel in raster1. Commission error yields the probability of a pixel in raster1 having the same value as the same pixel in raster2. Since these values are calculated for each hazardous feature type, they can provide more than just a general overview of differences and similarities between datasets and can specifically point to which hazardous feature types were classified consistently and which ones were not. In the context of this study it would appear rock classification drove accuracy down having the lowest omission and commission errors of all three-hazardous feature types. The full story of these statistics can be visualized on the cross-classification grid raster where exactly how the pixels changed or stayed the same between raster1 and raster2 is represented. For example, figure 4 indicates in yellow, pixels that were not classified as any hazardous feature is raster1, but were classified as rock in raster2. This is important in the context of sample-site selection as you would not want to mistakenly believe an area to be free of hazards that was not.

Figure 3: Cross-classification grid and calculated omission error, commission error, and over-all accuracy from cross-classification and tabulation analysis of raster1 and raster2.

	Boulder(1)	Rock(2)	Crater(3)	Not Classified (4)	Total
Boulder(1)	60226	510	0	101	60837
Rock(2)	852	375548	3465	159077	538942
Crater(3)	0	19902	75029	2710	97641
Not Classified(4)	19938	660034	25444	3150708	3856124
Total	81016	1055994	103938	3312596	4553544

Omission		Comission		Overall Accuracy
Boulder(1) =	74.34%	Boulder(1) =	99.00%	80.41%
Rock(2) =	35.56%	Rock(2) =	69.68%	
Crater(3) =	72.19%	Crater(3) =	76.84%	
Not Classified(4) =	95.11%	Not Classified(4) =	81.71%	

Figure 4: Cross-classification raster resulting from cross-classification and tabulation analysis of raster1 and raster2.



Conclusion: Cross-classification analysis does not eliminate human error in manual hazardous feature detection and classification, but it does inform the degree to which we can trust manual detection and classification. Furthermore, using QGIS to generate the hazardous feature dataset opens the door for the use of other GIS capabilities. Shapefiles and rasters are easily imported into spatial databases where queries can be run to calculate and visualize things like average grain size of rocks or size-frequency distribution of boulder and craters. In addition, other data that OSIRIS-REx collects from Bennu, like spectral or thermal data, can be used in spatial queries to further reconcile the chemical and physical properties of Bennu and ultimate solve spatial problems, the most important being to find the safest, most sample-able, and most scientifically valuable place to TAG on Bennu.

References:

[1] Lauretta D. S. (2015) *Handbook of Cosmic Hazards and Planetary Defense,* 543–565.

Acknowledgments: This work was supported by NASA contract NNM10AA11C.