Ashton Gray

ECE 597IP

32000589

Project 3: Felzenszwalb Region Boundary-based RAG

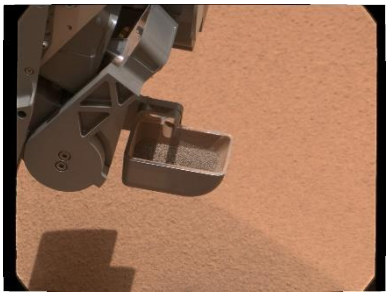
Background:

Similarly, to project 2, the Felzenszwalb algorithm will be used to over-segment the image, and a region adjacency graph (RAG) will be used on top of it to segment the rover from surrounding background. You can review the information on how the Felzenszwalb algorithm works in the background of project 2. However, in this project, instead of using a region adjacency graph that calculated the weight of the edges as average color, the edges of the RAG are calculated from the distance of a pixel and edges from the image itself. Therefore, in order to create the RAG, we will need the Felzenszwalb segmented image, and an edge map. These edge maps will be created in different ways, such as: Sobel, Canny, and difference of gaussians. Lastly, after the RAG's are created, we will use hierarchical merging to merge the segments at a given threshold.

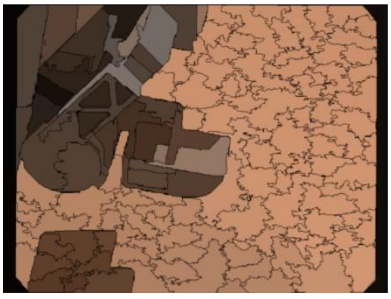
Below are the original images, along with the obtained Felzenszwalb over-segmentations that will be used with each RAG. It is important that when over-segmenting, there is no overlapping of rover to soil.

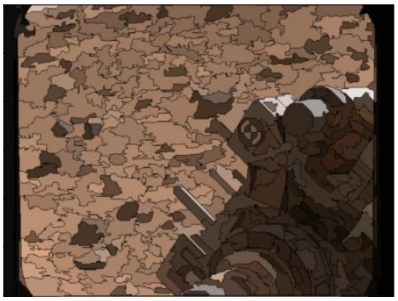
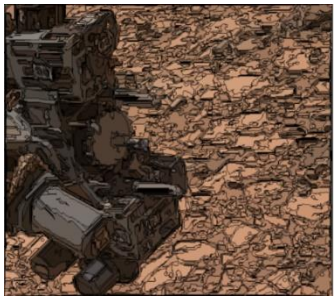
Original Images:

Image 1 Image 2 Image 3 Image 4




Felzenszwalb Over-Segmentations:



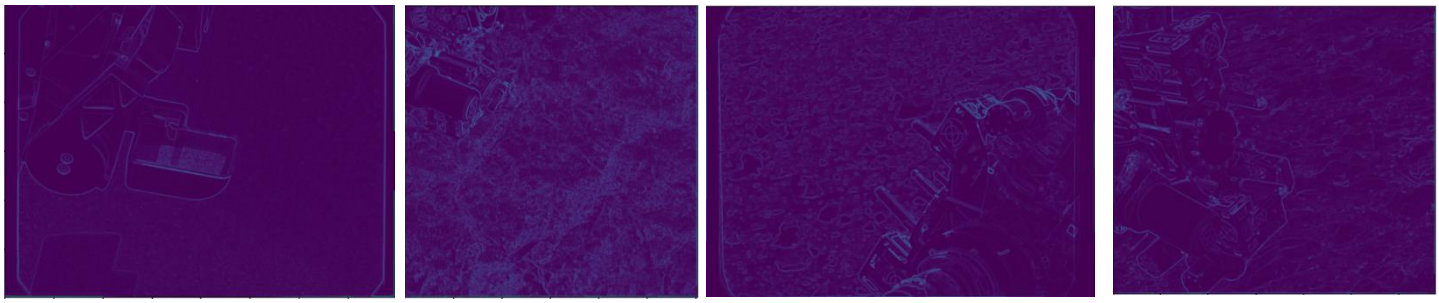
Scale: 10	Scale: 10	Scale: 2.5	Scale: 10
Sigma: 2	Sigma: 2	Sigma: 2	Sigma: 3.5
Min Size: 3000	Min Size: 100	Min Size: 1000	Min Size: 100

Edge Maps:

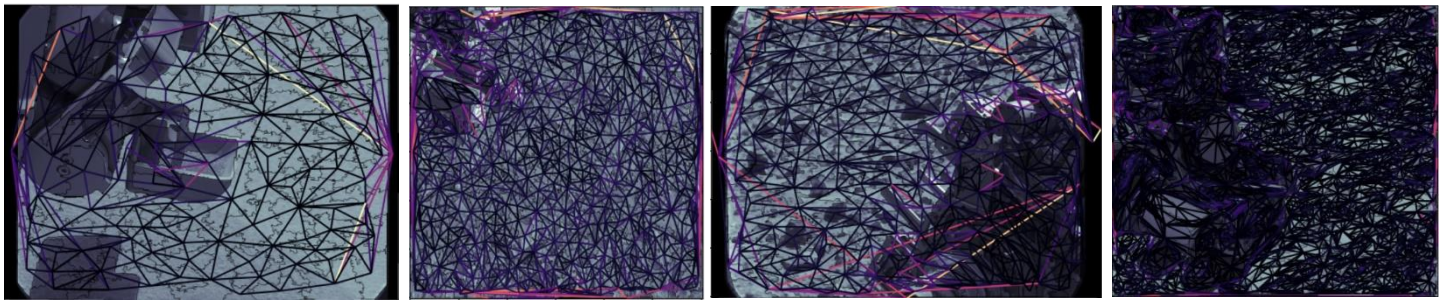
Sobel:

The first edge mapping tool we will use is Sobel. The Sobel filter uses two kernels, one that is rotated 90 degrees of the other, and performs a convolution on the image. The first kernel processes the image in the x direction, and the other in the y. Both are then combined together. This is done on the grayscale image, which essentially scans the image and emphasizes change in the gradient, meaning it emphasizes edges in the image.

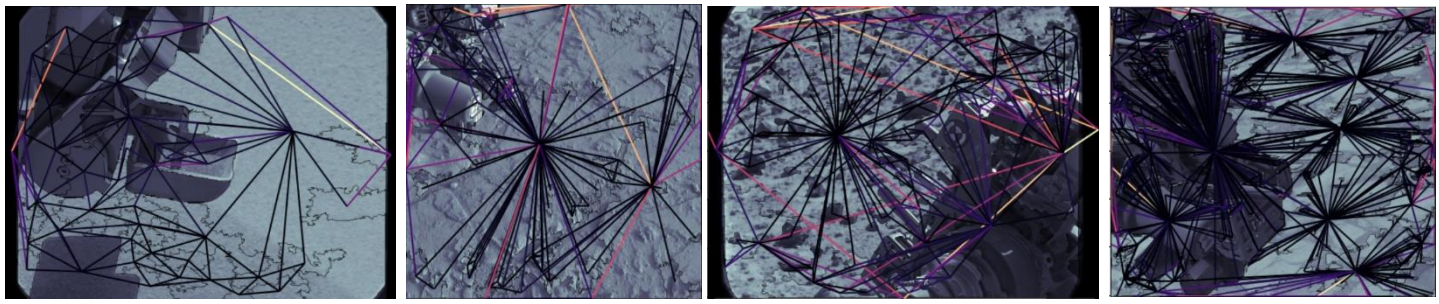
Image 1 Image 2 Image 3 Image 4



Above are the Sobel edge maps for each image. As you can see, for each image, the edges completely wrap the rover. This proves to be important for the RAG, otherwise segments of rover and soil are more likely to be combined together when using hierarchical merging.

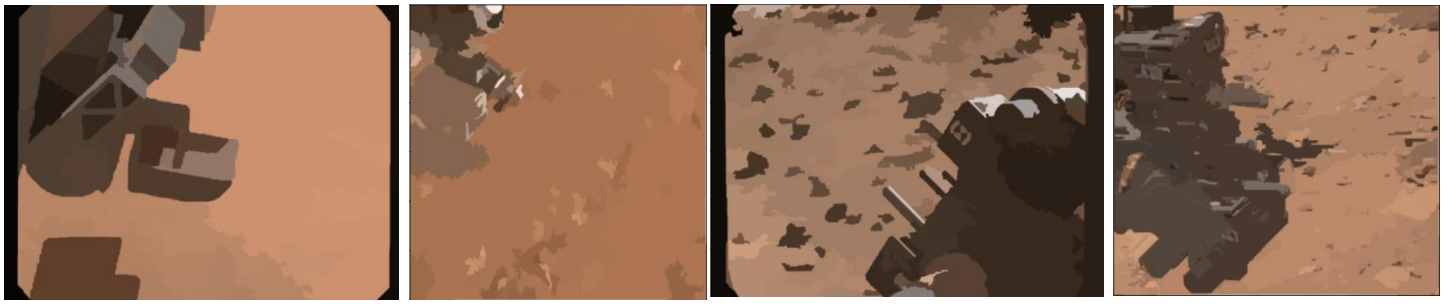


Here are the RAG's before hierarchical merging is done. As you can see, the RAGs are extremely clustered.



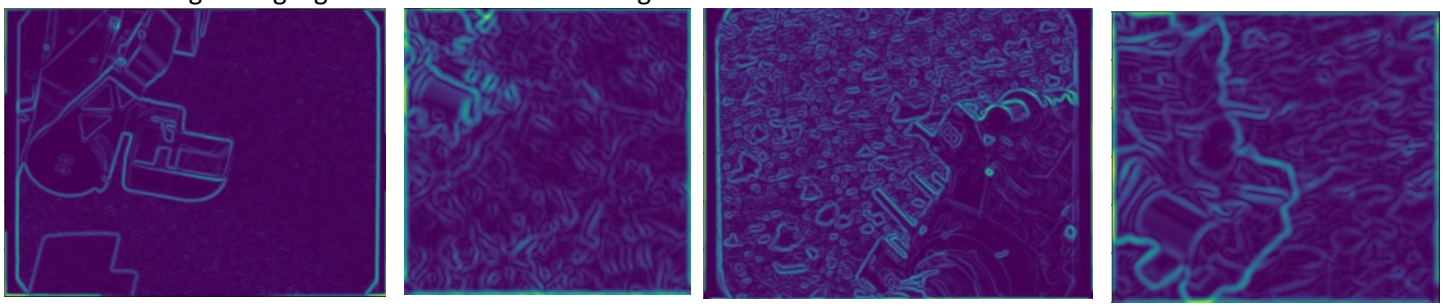
Threshold = 0.02 Threshold = 0.003 Threshold = 0.045 Threshold = 0.3

Above are the RAG's after hierarchical merging is done at a given threshold. We can tell that the lines that connect to a central point, are segmented together. Therefore, it is important to see that lines connect the rover to a central point, as well as lines connecting the soil to a central point.



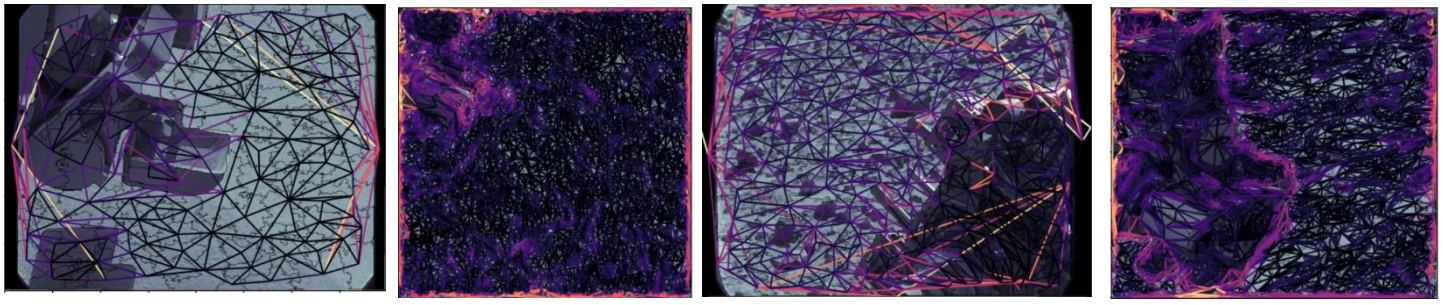
Here is the final segmented image. As you can see it was not perfect. For Image 2, parts of the rover were clustered into the same segment as soil, as well as, for all pictures, it was not able to segment into two discrete clusters of soil and rover. This is because of a limitation of the algorithm. The Sobel edge map shows edges including soil, and parts within the rover, therefore those things will be segmented on their own. Additionally, if the edge does not fully enclose the object, then parts of that object will bleed into the surrounding background and be segmented into the same cluster. However, as shown above in image 1, there is a clear distinction between rover, soil, and shadow, where there is no overlap. Therefore, the Sobel edge detection is not great for images with lots of edges.

However, due to that flaw, we can instead try to blur the image, and see the results. We will be blurring the image using a gaussian blur at different sigma values.

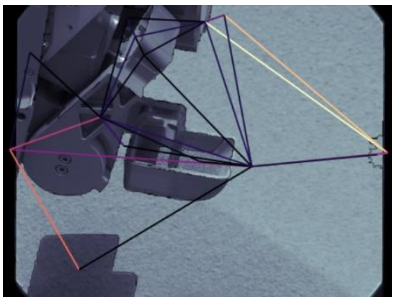


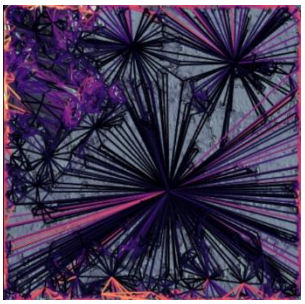
Sigma = 5 Sigma = 12 Sigma = 5 Sigma = 12

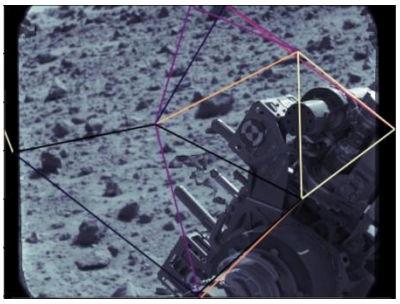
As you can see, the edges around the rovers are much more defined in the blurred Sobel images, rather than the non-blurred images. This will lead to better results.

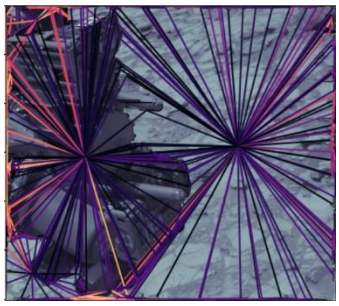


Above is the RAG before hierarchical merging is done. As you can see in these RAG's, the rovers are outlined with lines, showing that there is an edge.

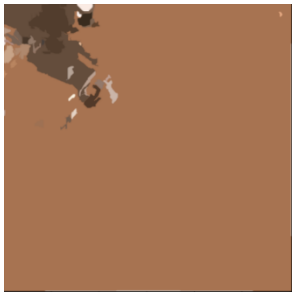

Threshold = 0.02


Threshold = 0.003


Threshold = 0.045


Threshold = 0.3

Here is the RAG after hierarchical merging. Compared to the non-blurred images, there are less edges, meaning there are larger clusters.



As you can see, the rover and surrounding soil were segmented into larger clusters, creating the distinction between rover and soil. In each image, except for image 2, the soil was segmented into one cluster.

Therefore, this shows that blurring the image before using Sobel edge mapping is much more efficient, and leads to better results, given the same thresholds.

Canny:

Canny edge mapping is another way to create an edge map. This edge detection method takes advantage of the perks of blurring the image seen above. So, this method, blurs the image in a similar way to gaussian. It then finds potential edges, and thins them to be only one pixel wide. It does this by calculating the gradient and removes the pixels that are not a maximum of the gradient (not an edge).

Image 1


Sigma = 2.1

Image 2

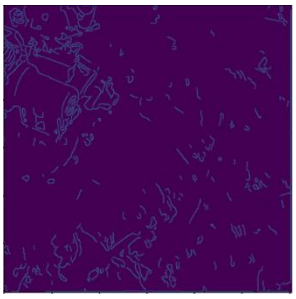

Sigma = 3.5

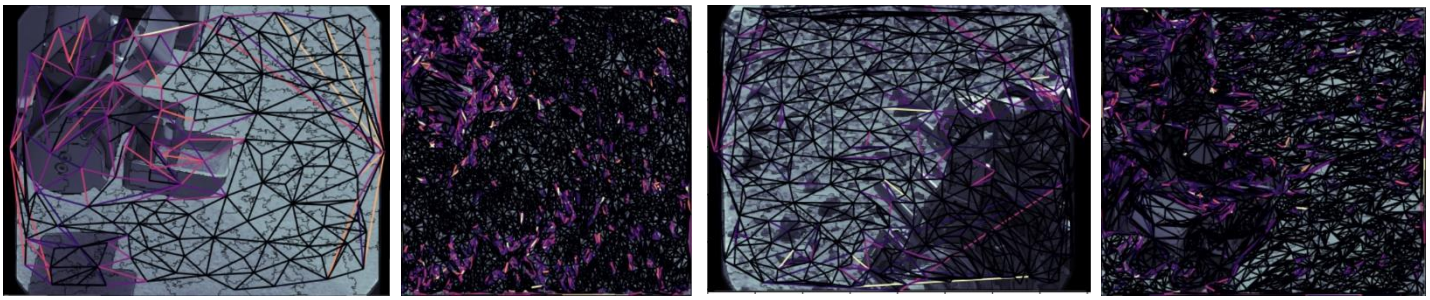
Image 3


Sigma = 6

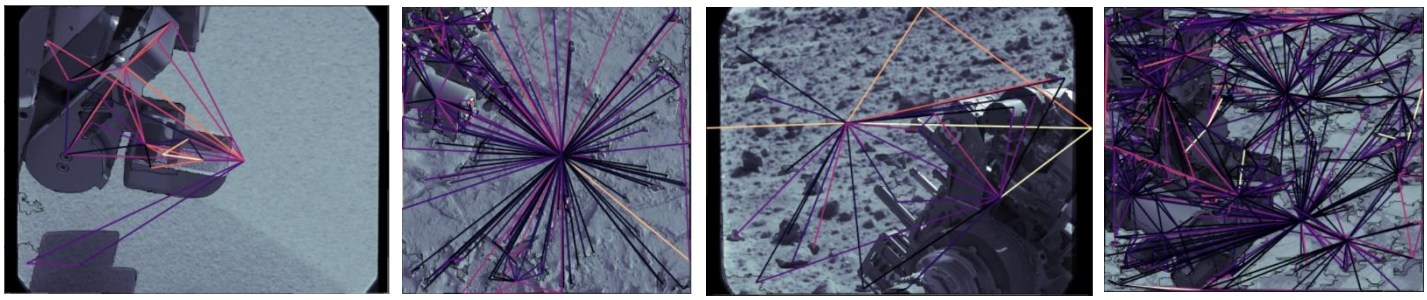
Image 4


Sigma = 3

Above are the one-pixel wide edges calculated for each image. Similarly to Sobel, it was found that the best RAG is found, when the edges of the rover are completely connected, and therefore will not bleed into the surrounding soil. This, however, is a limitation to using canny edge detection because when making sure to include the entirety of the rover's edges, rocks in the surrounding soil will also keep their edges. This works well for image 1 and 3, not so much for 2 and 4, where parts of the soil are emphasized.

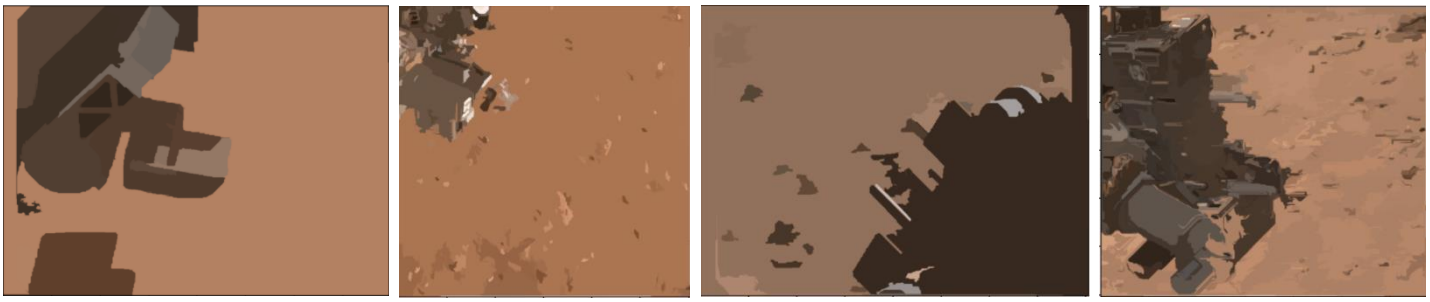


Above is the RAG before hierarchical merging is done.



Threshold = 0.02 Threshold = 0.003 Threshold = 0.045 Threshold = 0.3

Above is the RAG after hierarchical merging is done at specific threshold values. As you can see, these values were picked so that the edges connected parts of the rover to itself, and the soil also to itself. In image 1, you can see that the shadow is also in its own cluster.



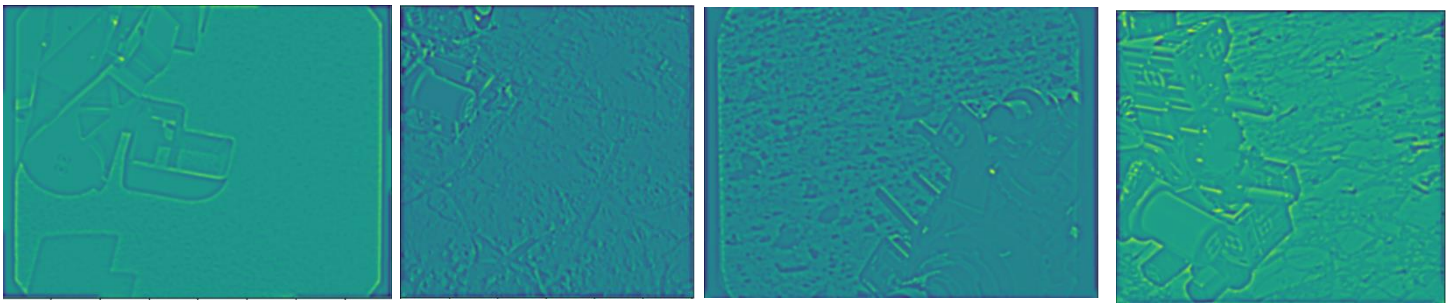
Above are the results of hierarchical merging. In image 1, the soil is in its own cluster, as well as the shadow. For image 2, 3, and 4, you can see parts of the soil is in its own cluster. This is a limitation of the algorithm, where the edges of rocks in the soil are emphasized and therefore impacts the RAG. If this were to be ignored, then parts of the rover would be segmented into the same clusters as the soil.

Overall, this was better than using Sobel edge mapping without blurring, but not as good as Sobel edge mapping with the use of blur.

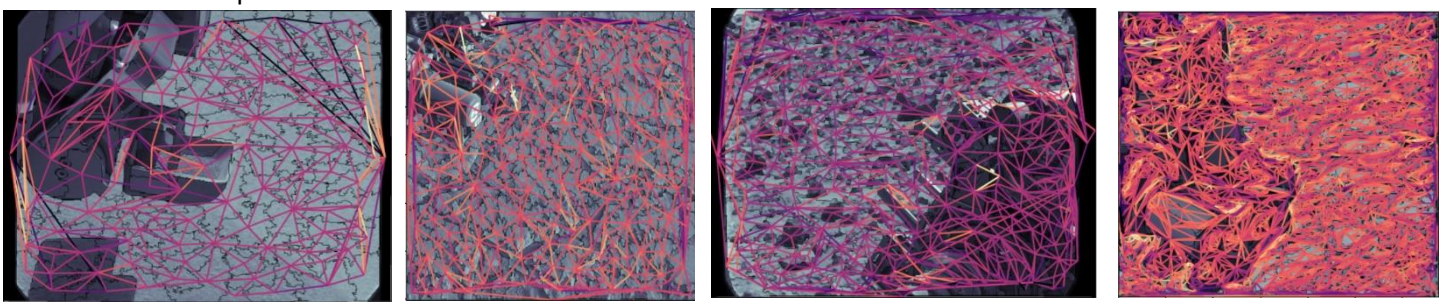
Difference-Of-Gaussians:

Lastly, we can use the difference of gaussians for edge mapping. As it proved in the last two examples, blurring the image was very useful. Therefore, we will try the difference of gaussians edge mapping method. In this method, two different gaussian kernels are used. One with a low sigma, and the other with a higher sigma. The resulting low sigma blurred image is then subtracted from the high sigma blurred image. This creates an image where the high frequency components are more pronounced (edges), and the low frequency components are removed.

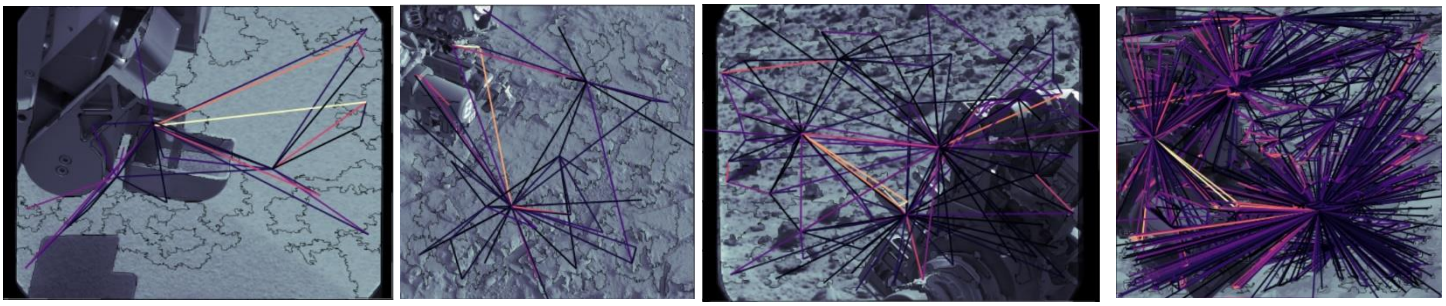
Image 1 Image 2 Image 3 Image 4



Above is the edge-map after difference of gaussians was used, with the low sigma equal to 5, and the high sigma equal to 9 for each image. As you can see, the edges are not very pronounced, and therefore will lead to poor results.

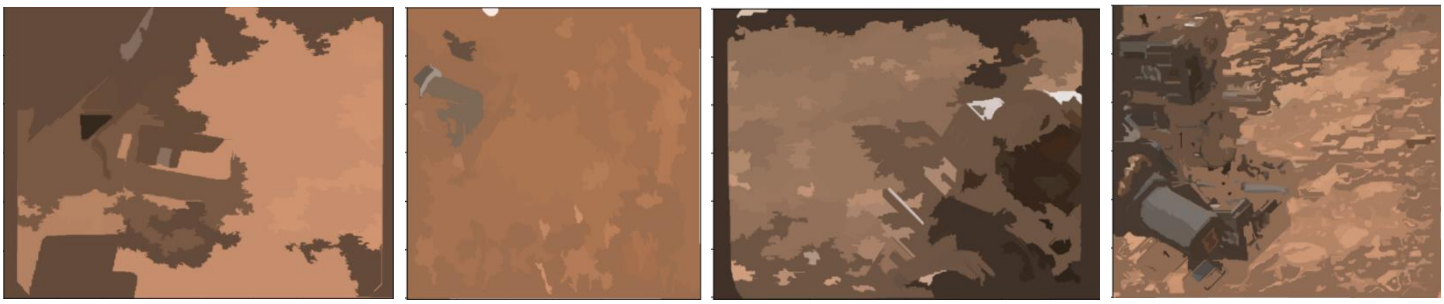


Above is the RAG before hierarchical merging is used.



Threshold = 0.002 Threshold = 0.0001 Threshold = 0.0001 Threshold = 0.0001

Above is the RAG after hierarchical merging is used with given thresholds.



Above are the results from using the difference of gaussians for edge mapping.

As you can see, the difference of gaussians did not give a good result. This is due to a limitation of creating the edge map. The difference of gaussians does not create an image with distinct edges, instead in these cases just blurred the image together. This can be seen in the RAG, where it would keep the edges between parts of the rover and soil. Therefore, in the resulting image you can see clusters where the soil and rover are in the same cluster.

Conclusion:

In conclusion, the blurred Sobel edge map was the most effective edge mapping for the boundary-based RAG. This was because, in all cases, blurring the black and white image created the most distinct edges, however, with Sobel, they were the most prominent. It was also found, that in the original RAG, before hierarchical merging was done, the best results came from when the rover had distinct outlines, as seen in Sobel. This is because distinct edges were fed into the RAG, and were able to create high valued RAG edges around the rover. Also, it was found that with the hierarchical RAG, it was a good sign to see fewer lines connecting the edges of rover to the center of the rover. This means that the rover would be segmented into less clusters. The boundary-based RAG has perks over the mean-color based RAG, by being able to actually detect if there is an edge between the rover and soil, where mean-color could not. However, this only works if the edge mapping can show clear edges of object, if not, the result can be much worse than just using the mean-color RAG.