Mars 2020 Rover Dust Analysis for Drill

Team Hindsight

Introduction

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JPL's Mission to Understand Mars

JPL is a federally funded NASA research and development center whose primary role is to construct and operate planetary robotic spacecraft. Mars is a good place to start looking for answers for a few reasons. JPL has sent many missions to Mars with the goal of looking for evidence that Mars once had the conditions necessary to support life.

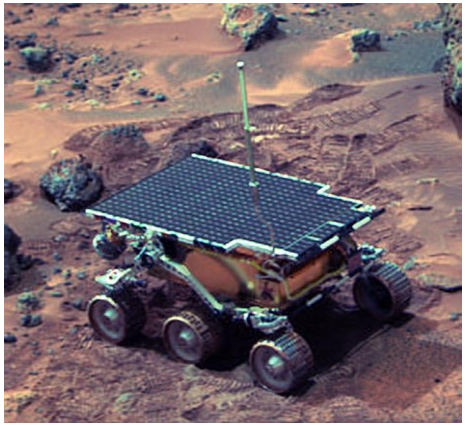


Figure 1.0. Pathfinder

Figure 1.1. Spirit and Opportunity

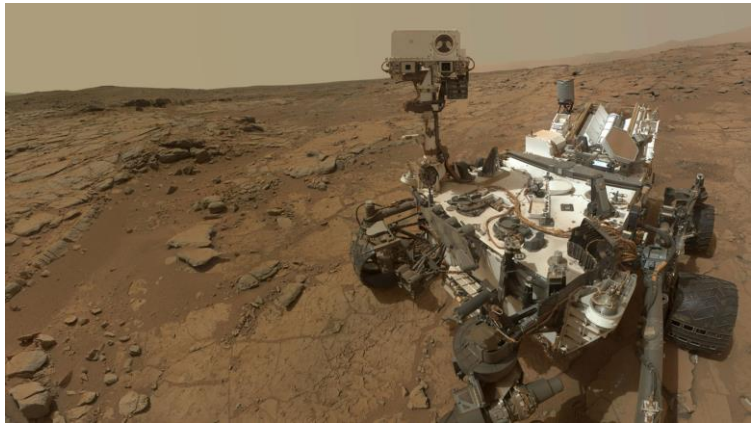


Figure 1.2. Curiosity

Mars 2020 (M2020)

The primary goal of JPL's latest rover, M2020 will be to look for evidence of past life on Mars by analyzing and collecting samples of the Martian surface which will then be picked up, and returned to Earth by a future mission.

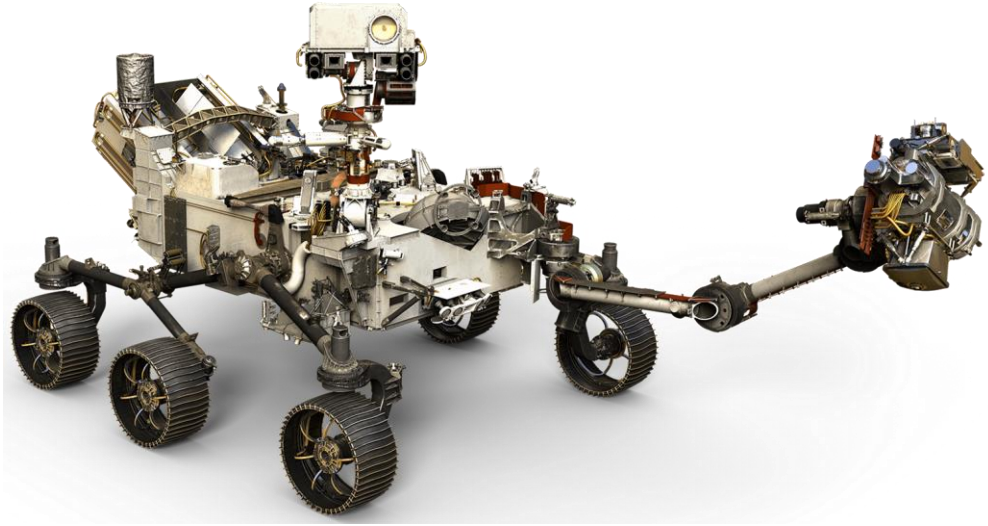


Figure 2.0. Mars 2020

Challenge facing JPL

When the rover drills it creates dust that obscures the hole. JPL's solution is to use compressed gas to blow dust out of the hole.

Figure 3.0. Before dust removal

Figure 3.1. After dust removal

Why JPL's testing method is a problem:

- Slow
- Inconsistent

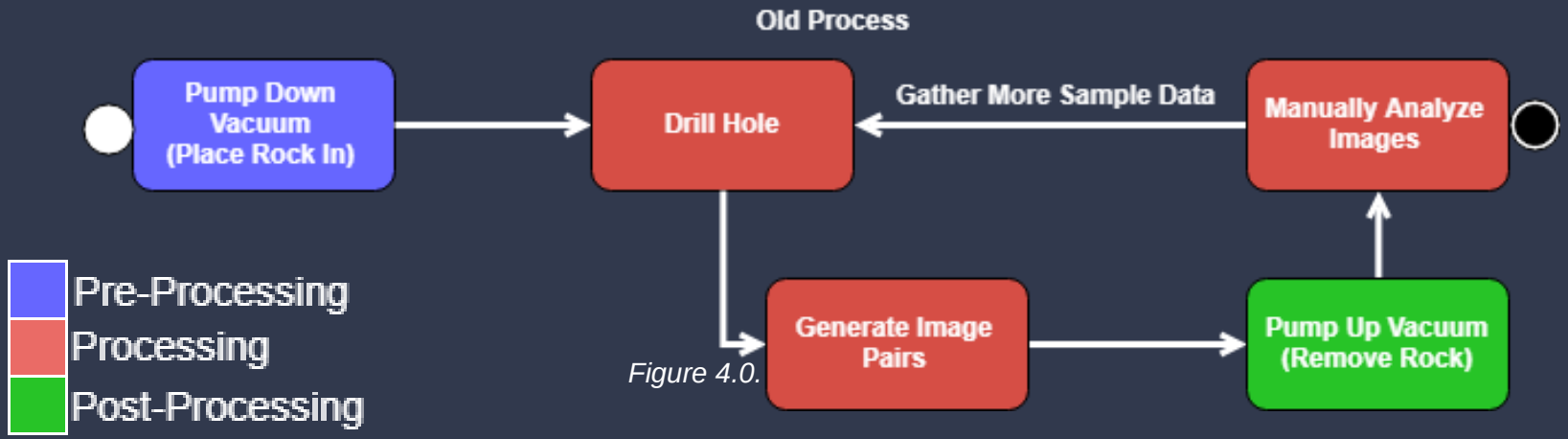


Figure 4.0.

Solution Overview

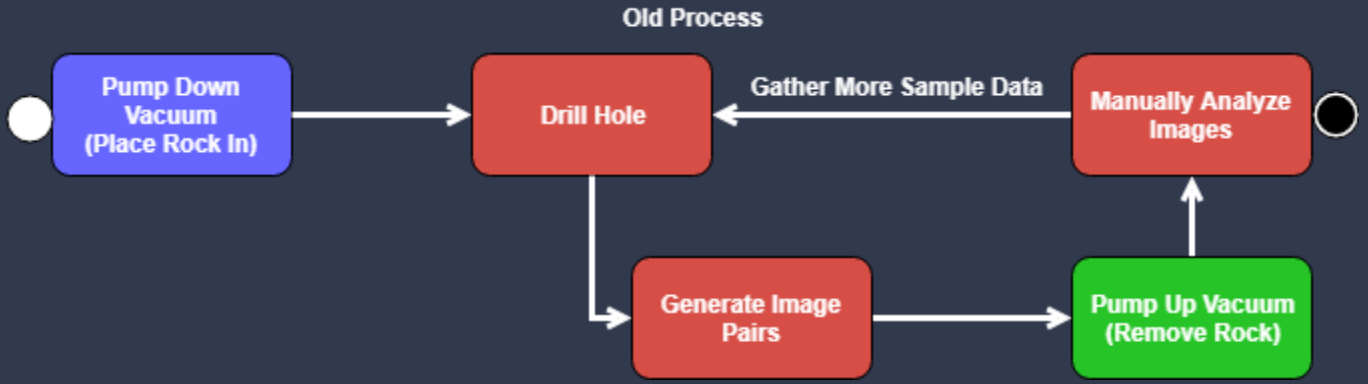


Figure 5.0. Old process from JPL

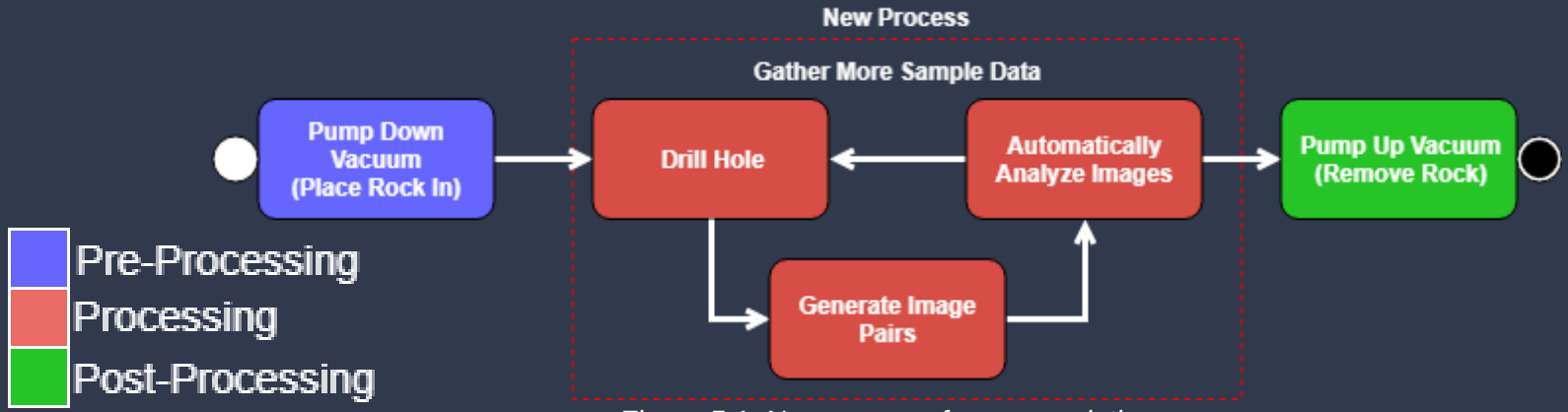


Figure 5.1. New process from our solution

Our Solution

Our software includes the following to the process:

- Faster :
  - No longer need to depressurize vacuum chamber
  - Image analysis speeds up to less than 5 minutes (from one hour) per image pair
- More consistent:
  - For all images per rock type
  - Less prone to human error
- Further improvements and flexibility
  - Can be parallelized
  - Algorithms added or changed

Requirements/Specs review

- Functional
  - Handle batch of images
  - Analyze image(s) for dust
  - Mark areas of dust coverage
  - Be within 10% of JPL’s values

Figure 6.0. Example abrasion analysis

- Non-Functional
  - Display percentage of areas cleared
  - Display after air blast and analyzed images in a GUI
  - Should take no longer than five minutes per image pair

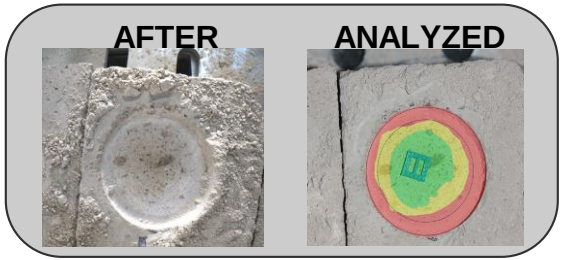


Figure 6.1. Examples of after and JPL analyzed image

Architecture Overview

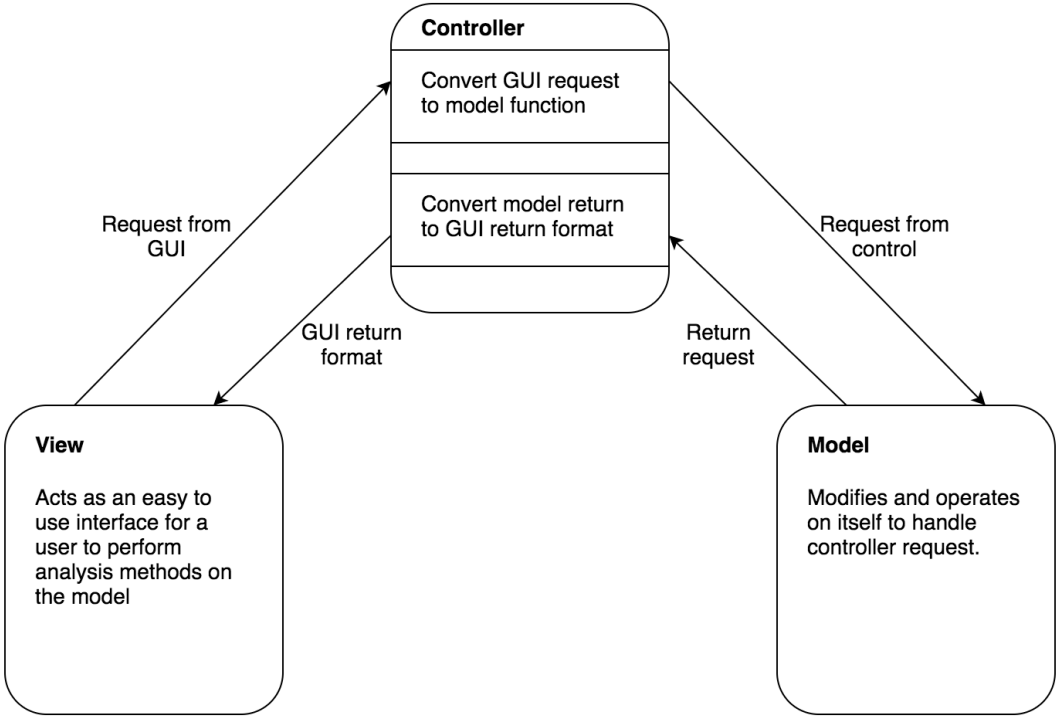


Figure 7.0. High level architecture of the processing pipeline

- Model View Controller (MVC)
  - Graphical User Interface integration
  - Logic Separation
  - Parallel Development

Implementation

Model:

- Image
- Communicates with Controller through return values
- Uses third party libraries
  - Numpy
  - OpenCV

Figure 8.0. Before image data

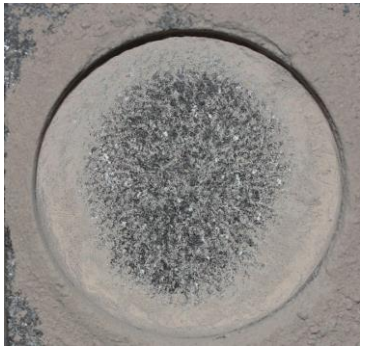


Figure 8.1. After image data

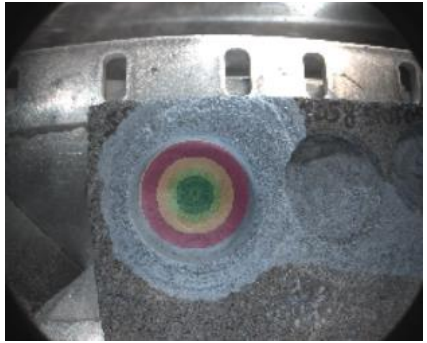


Figure 8.2. Analyzed image data

Implementation

View:

- Window Class
- Analysis Window Class
- Communicates with Controller using Config Class
- Uses tkinter

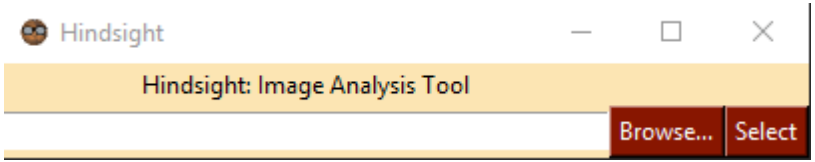


Figure 9.0. Window

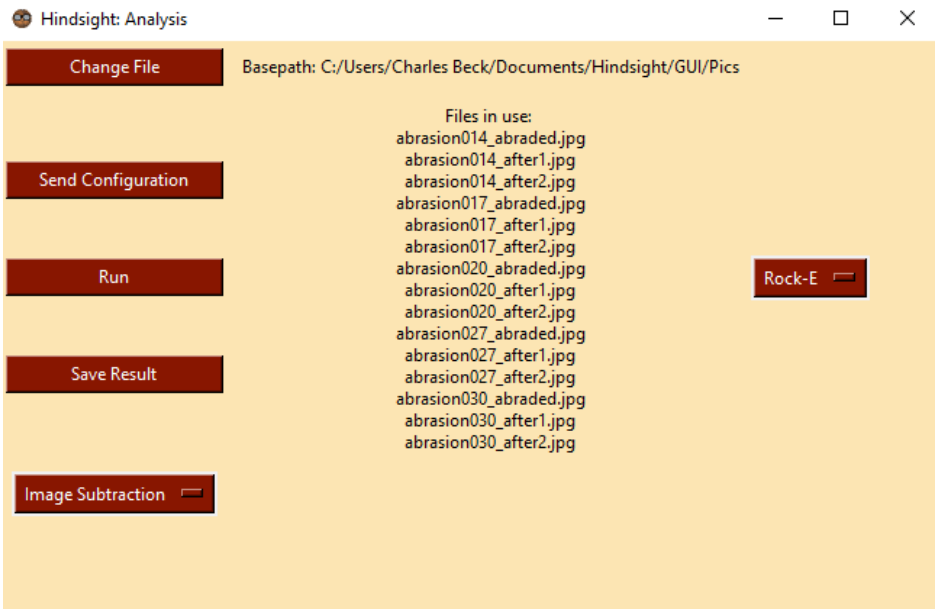


Figure 9.1. Analysis Window

Implementation

Controller:

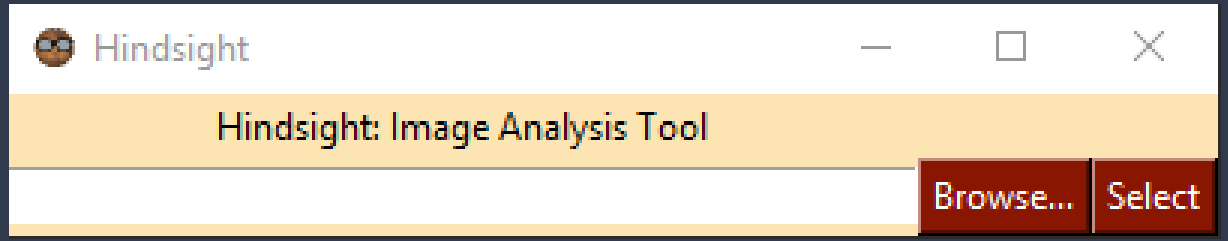
- Control Class
- control_funcs
- Sends returns from Model to View
- Applys Config functions to Model
- Uses Pandas Dataframe

	after_image	before_image	image_group	output_image
0	<image.image.Image object at 0x10601a6d8>	<image.image.Image object at 0x10601a128>	abrasion020_abraded.JPG	None

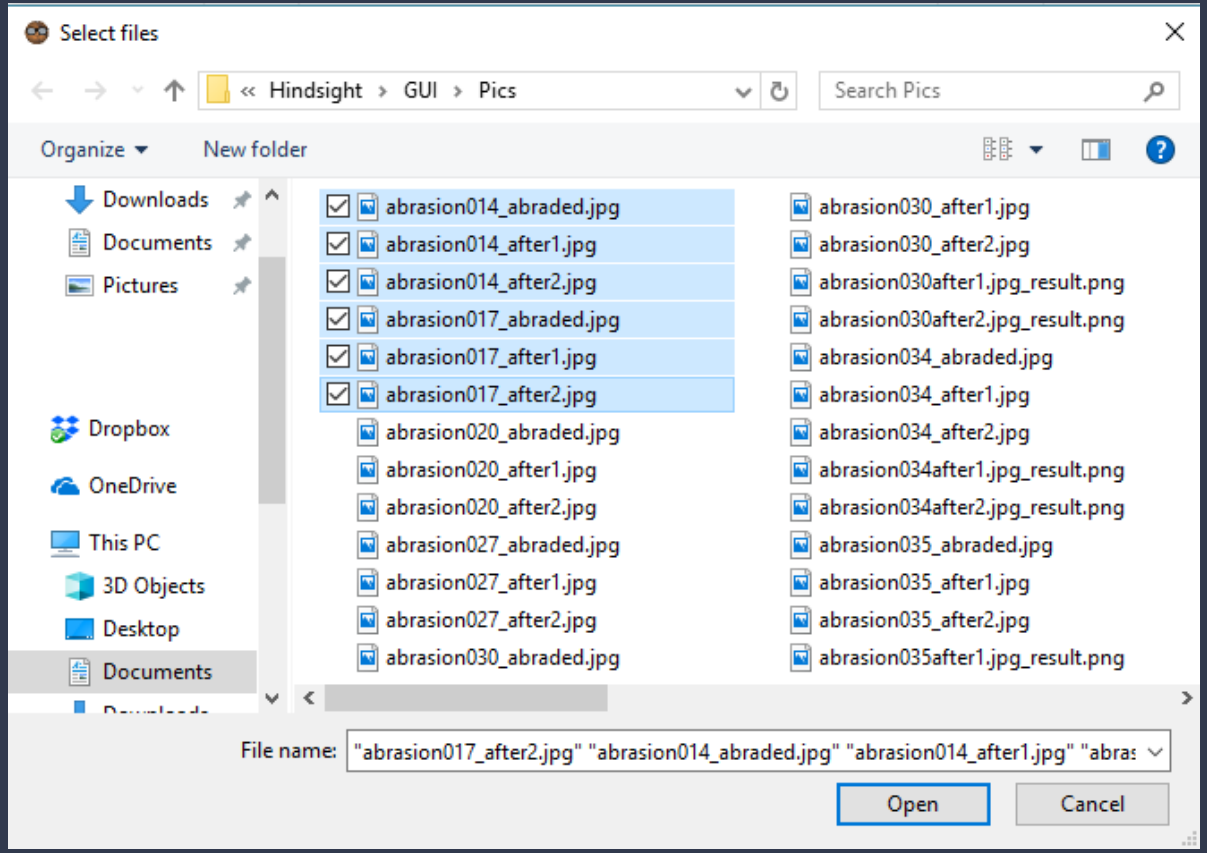
Figure 10.0. Controller Pandas Dataframe

Product Overview

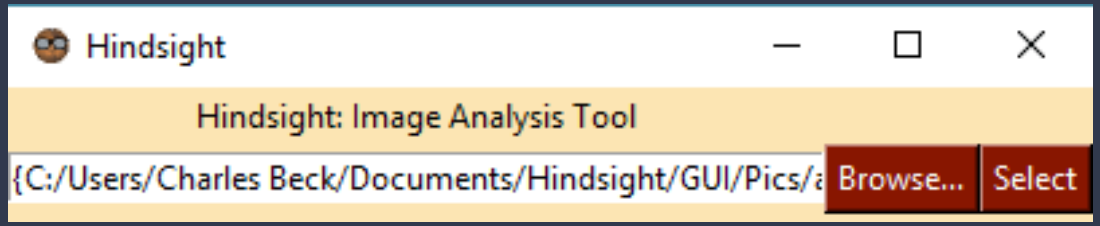
Start



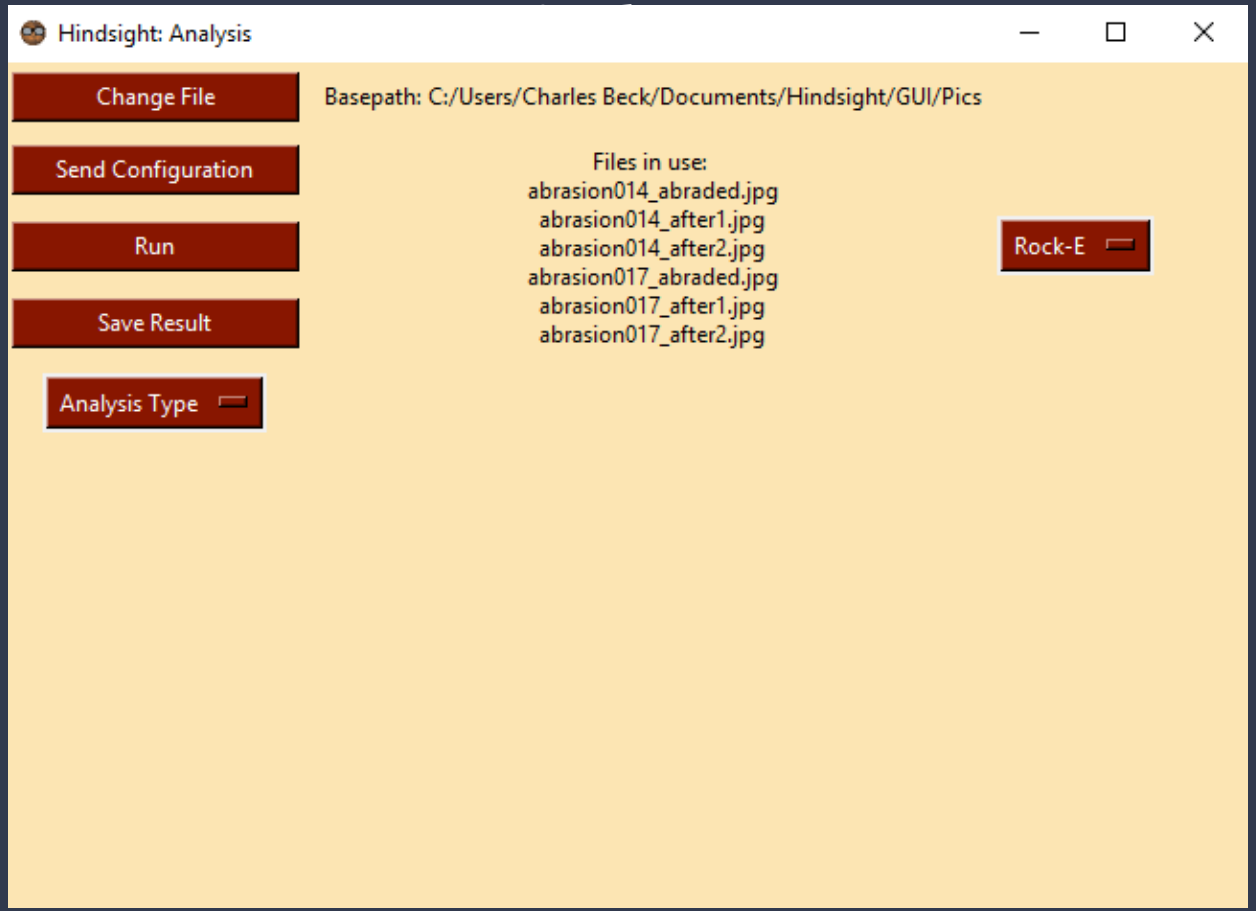
File Browser



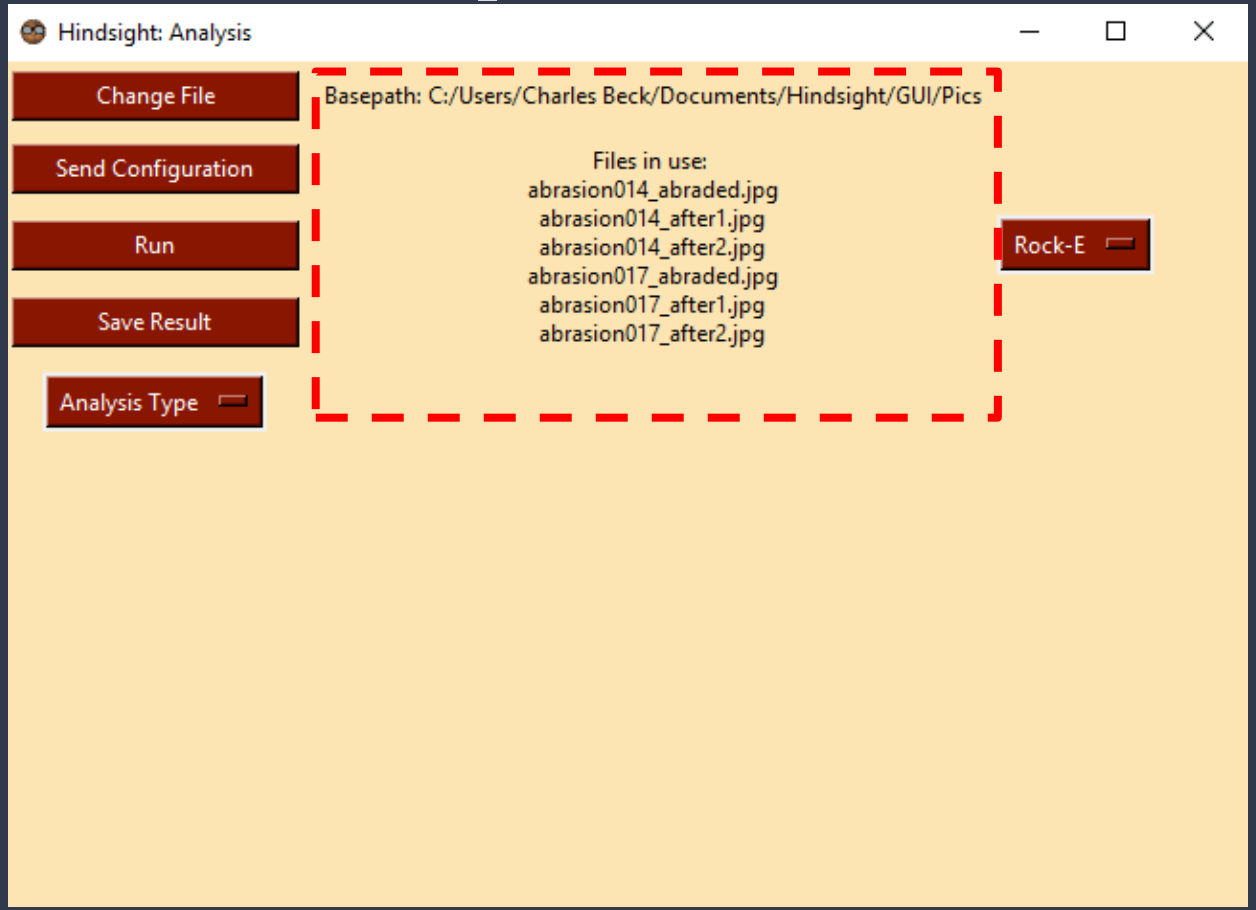
Selected


Hindsight
Hindsight: Image Analysis Tool
{C:/Users/Charles Beck/Documents/Hindsight/GUI/Pics/a
Browse...
Select

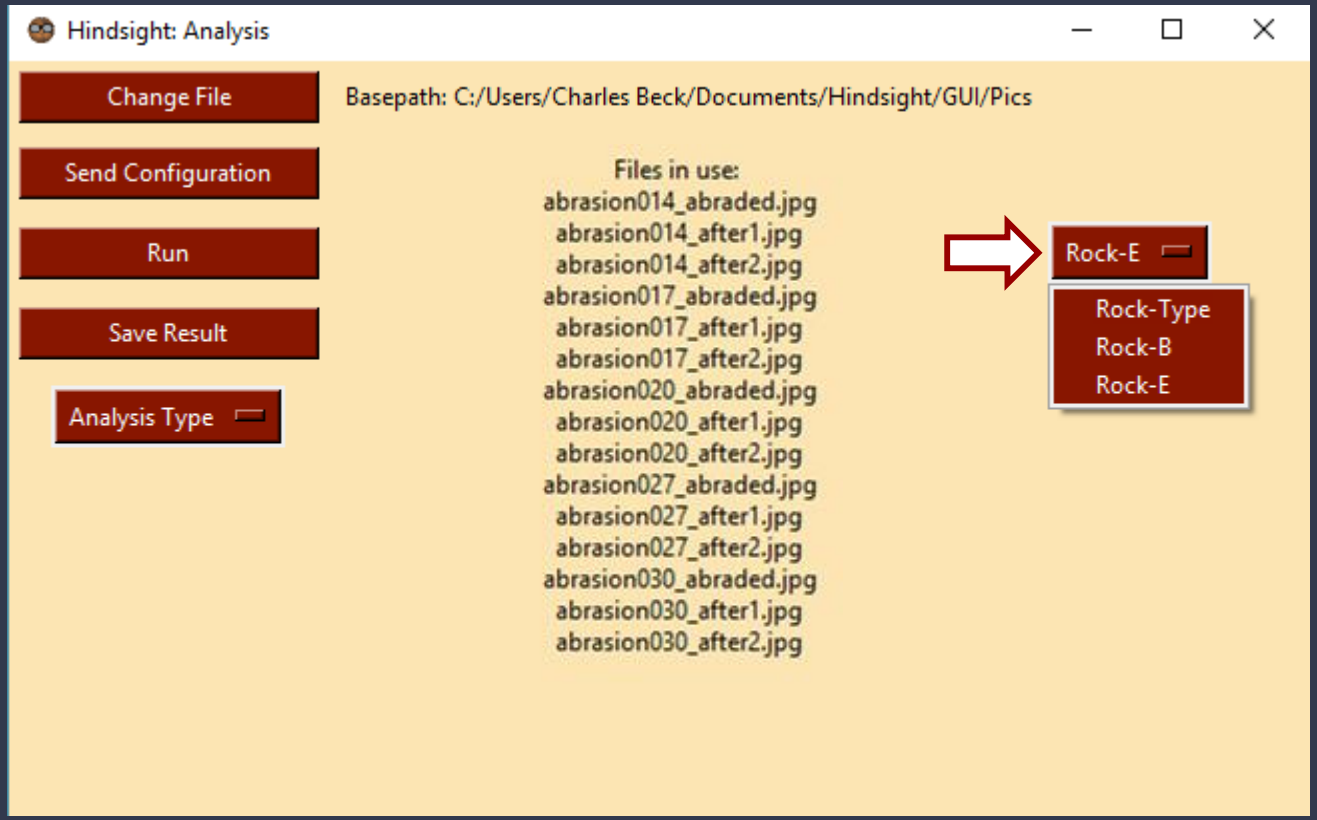
Analysis


Hindsight: Analysis
Change File
Basepath: C:/Users/Charles Beck/Documents/Hindsight/GUI/Pics
Send Configuration
Files in use:
abrasion014_abraded.jpg
abrasion014_after1.jpg
abrasion014_after2.jpg
abrasion017_abraded.jpg
abrasion017_after1.jpg
abrasion017_after2.jpg
Run
Rock-E
Save Result
Analysis Type

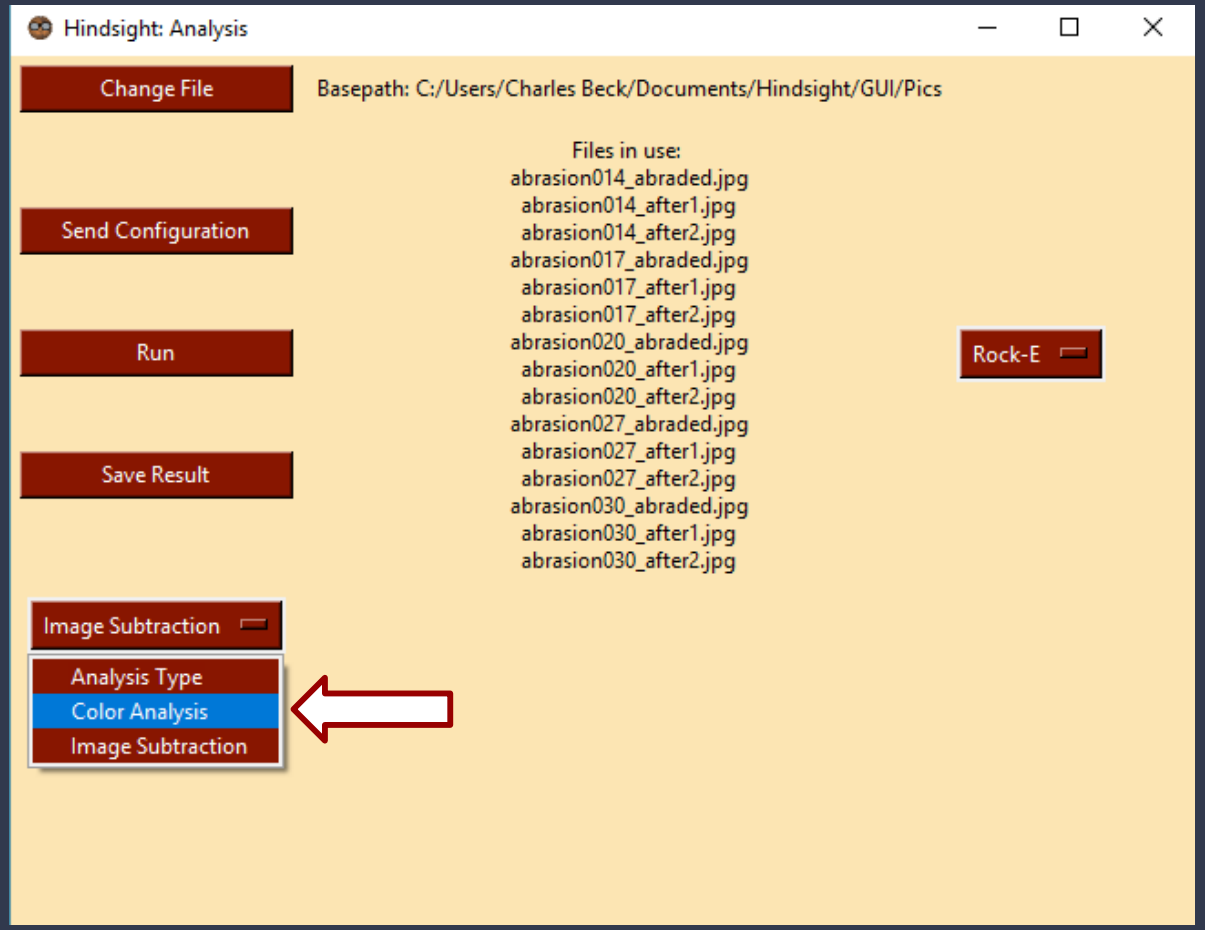
Basepath - Filenames

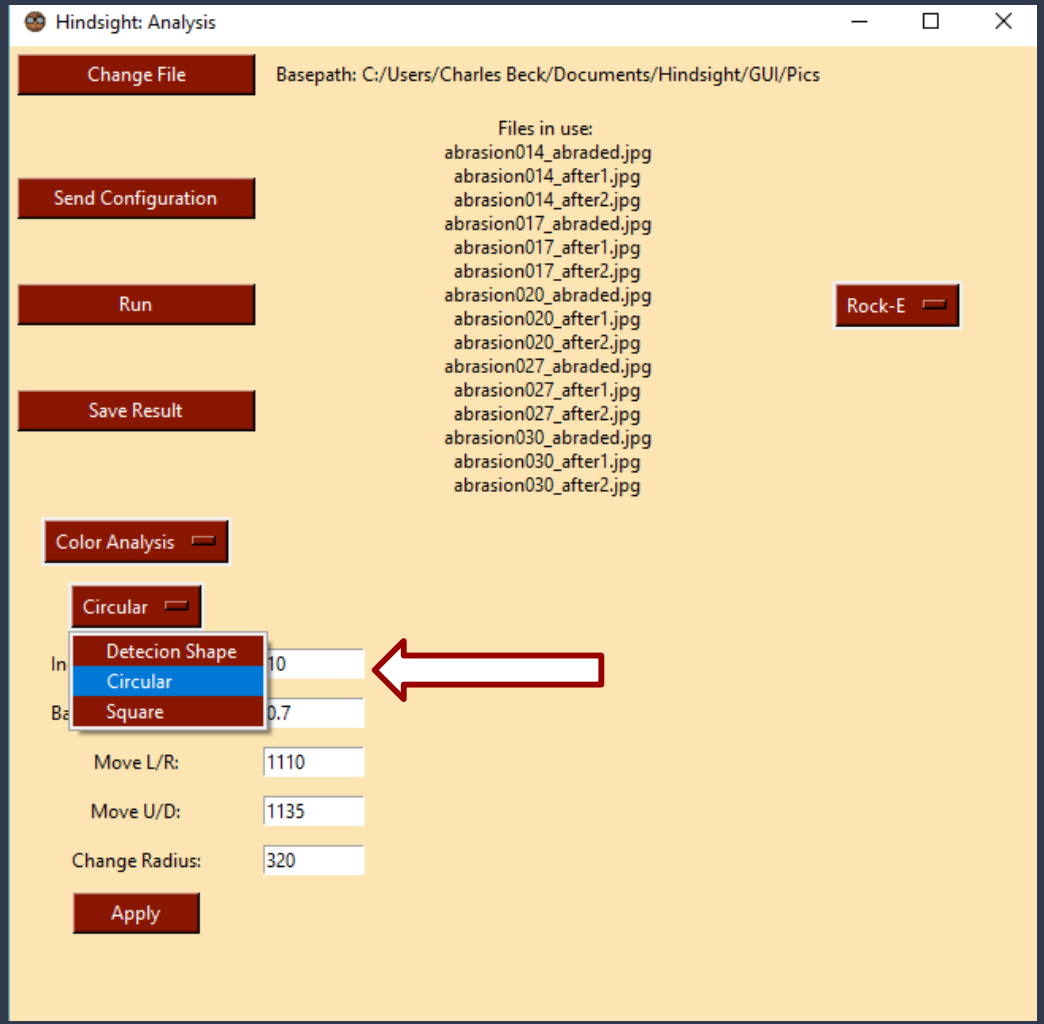


Analysis Window - Rock Type



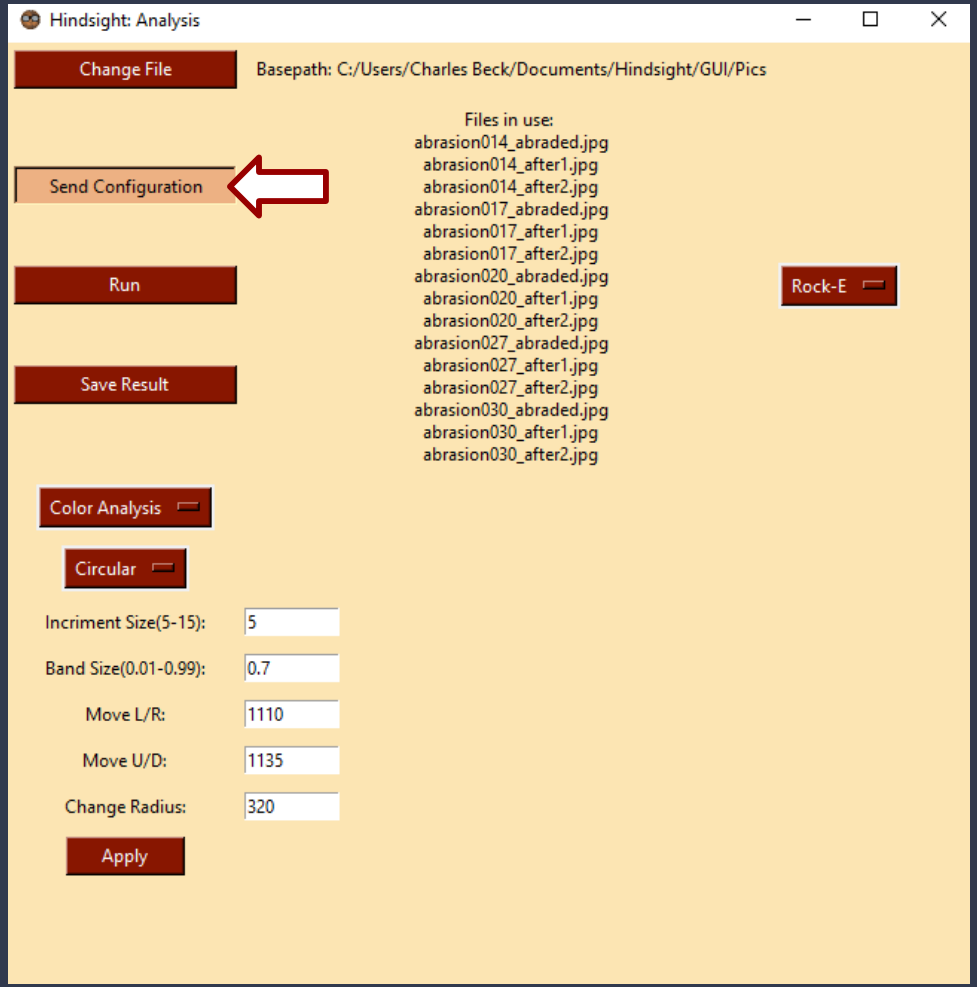
Select Image Analysis type



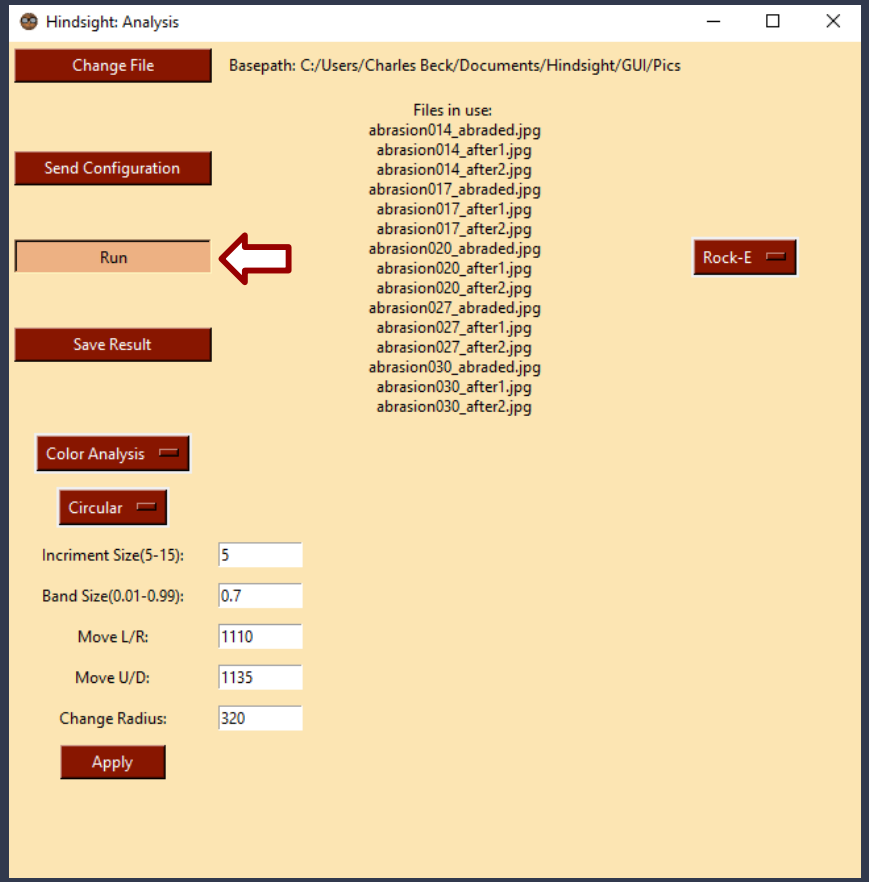


Select Detection shape

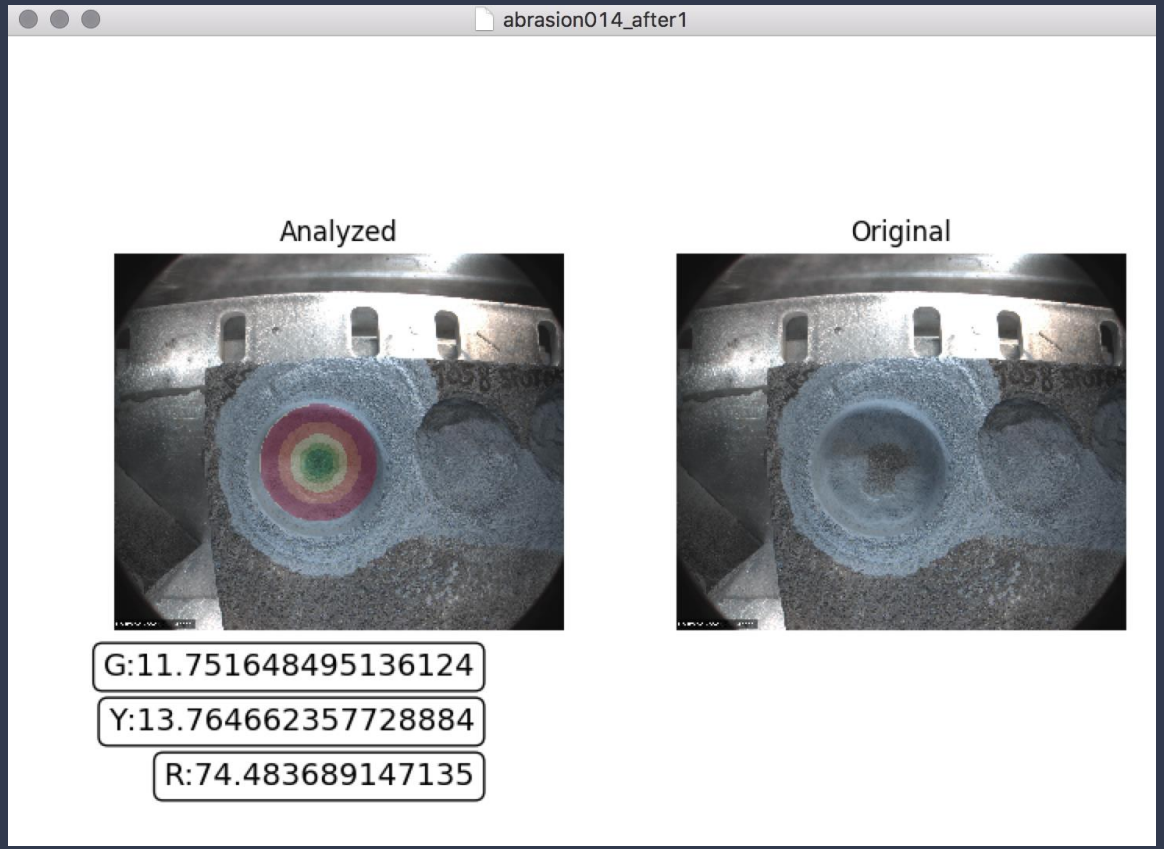
Send Configuration to Control



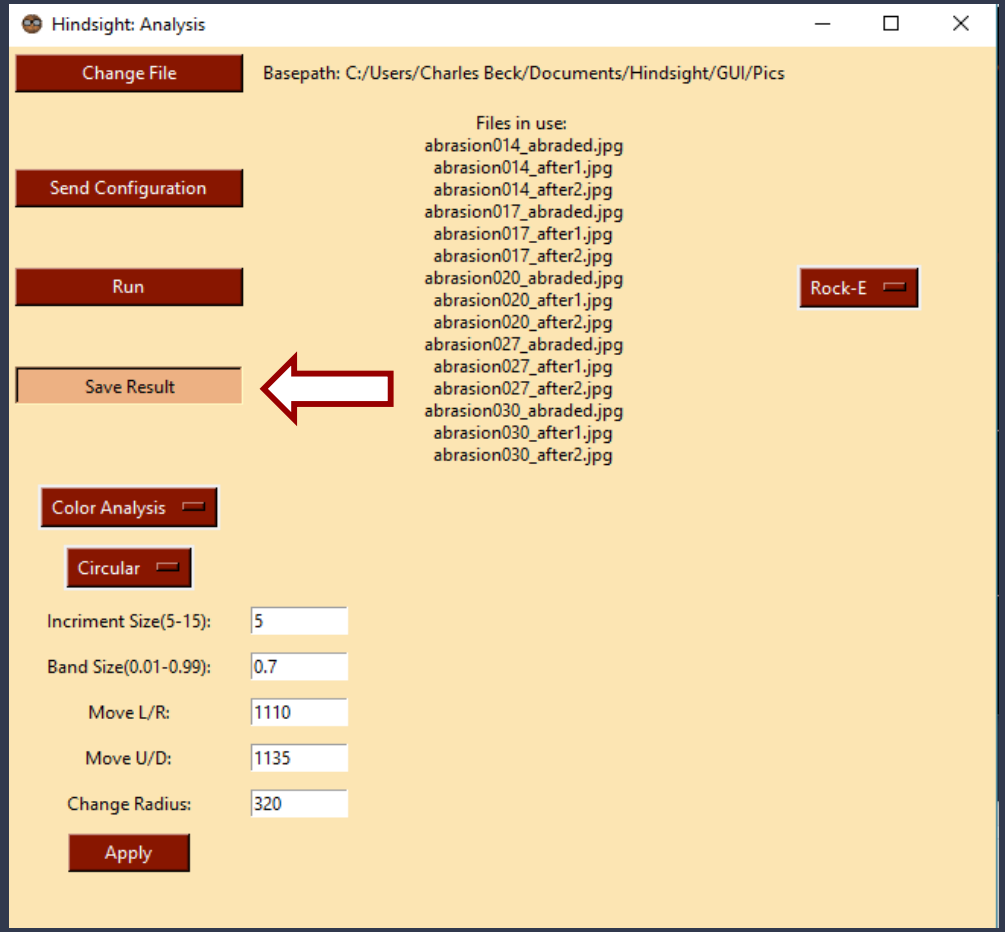
Running Analysis

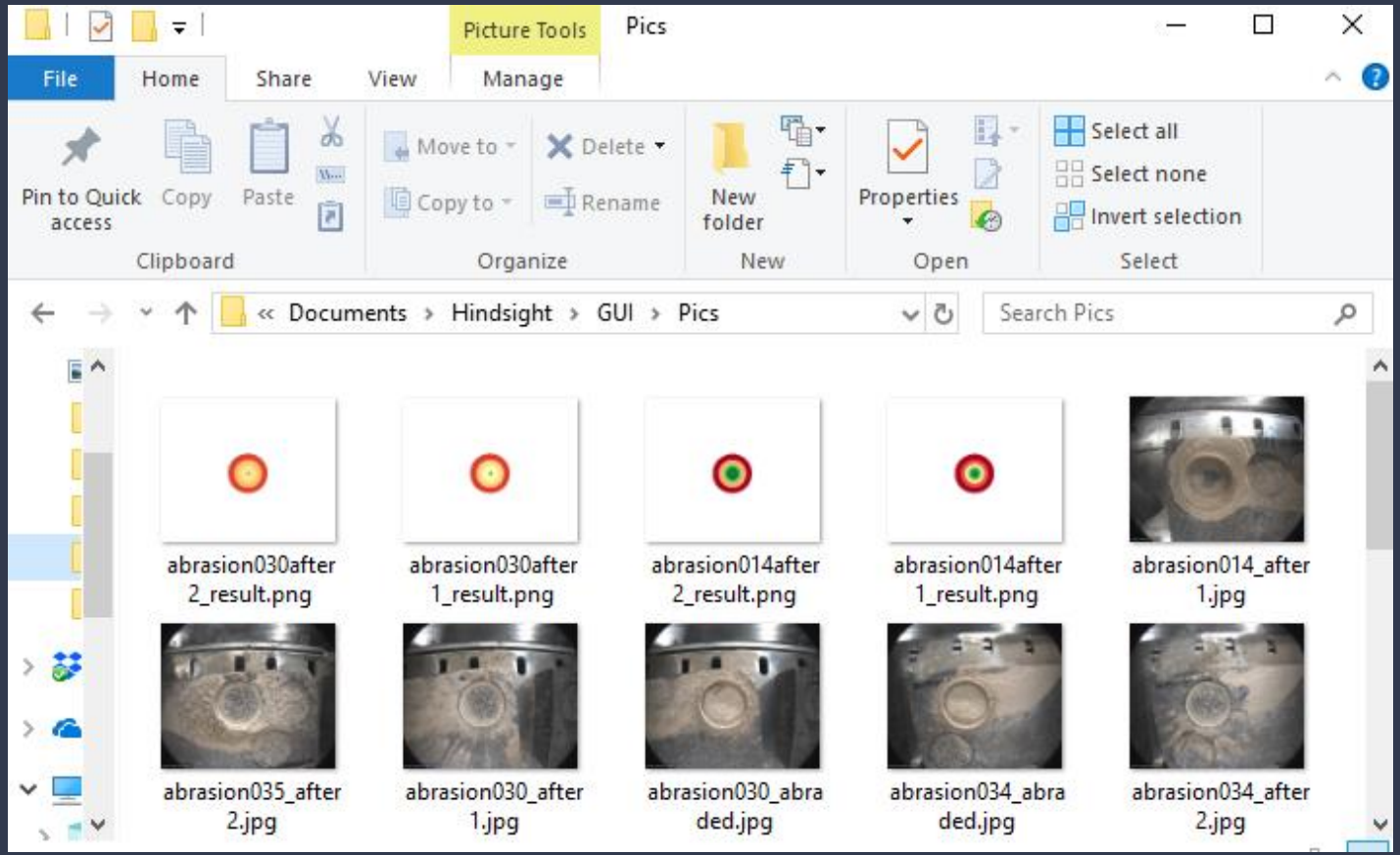


Output- Display For Each Analyzed Image



Save


Hindsight: Analysis
Change File
Basepath: C:/Users/Charles Beck/Documents/Hindsight/GUI/Pics
Files in use:
abrasion014_abraded.jpg
abrasion014_after1.jpg
abrasion014_after2.jpg
abrasion017_abraded.jpg
abrasion017_after1.jpg
abrasion017_after2.jpg
abrasion020_abraded.jpg
abrasion020_after1.jpg
abrasion020_after2.jpg
abrasion027_abraded.jpg
abrasion027_after1.jpg
abrasion027_after2.jpg
abrasion030_abraded.jpg
abrasion030_after1.jpg
abrasion030_after2.jpg
Send Configuration
Run
Rock-E
Save Result
Color Analysis
Circular
Incriment Size(5-15):
5
Band Size(0.01-0.99):
0.7
Move L/R:
1110
Move U/D:
1135
Change Radius:
320
Apply


Picture Tools
Pics
File
Home
Share
View
Manage
Pin to Quick access
Copy
Paste
Move to
Delete
Copy to
Rename
New folder
Properties
Select all
Select none
Invert selection
Clipboard
Organize
New
Open
Select
« Documents › Hindsight › GUI › Pics
Search Pics
abrasion030after2_result.png
abrasion030after1_result.png
abrasion014after2_result.png
abrasion014after1_result.png
abrasion014_after1.jpg
abrasion035_after2.jpg
abrasion030_after1.jpg
abrasion030_abraded.jpg
abrasion034_abraded.jpg
abrasion034_after2.jpg

Challenges and Resolutions

- Edge detection
  - After applying multiple algorithms and methods for detecting the edge, we found they led to a dead end
  - Resolution: Client suggested we do it based on camera parameters
    - Another team at JPL is working on edge detection alone
  - Status: Resolved
- Color segmentation for other rock types
  - What we currently have for Rock Type E doesn’t work/may not work for other rock types
  - Resolution: Each rock type has a customized algorithm
  - Status: Have prototype for Rock Type B with further improvements on the way

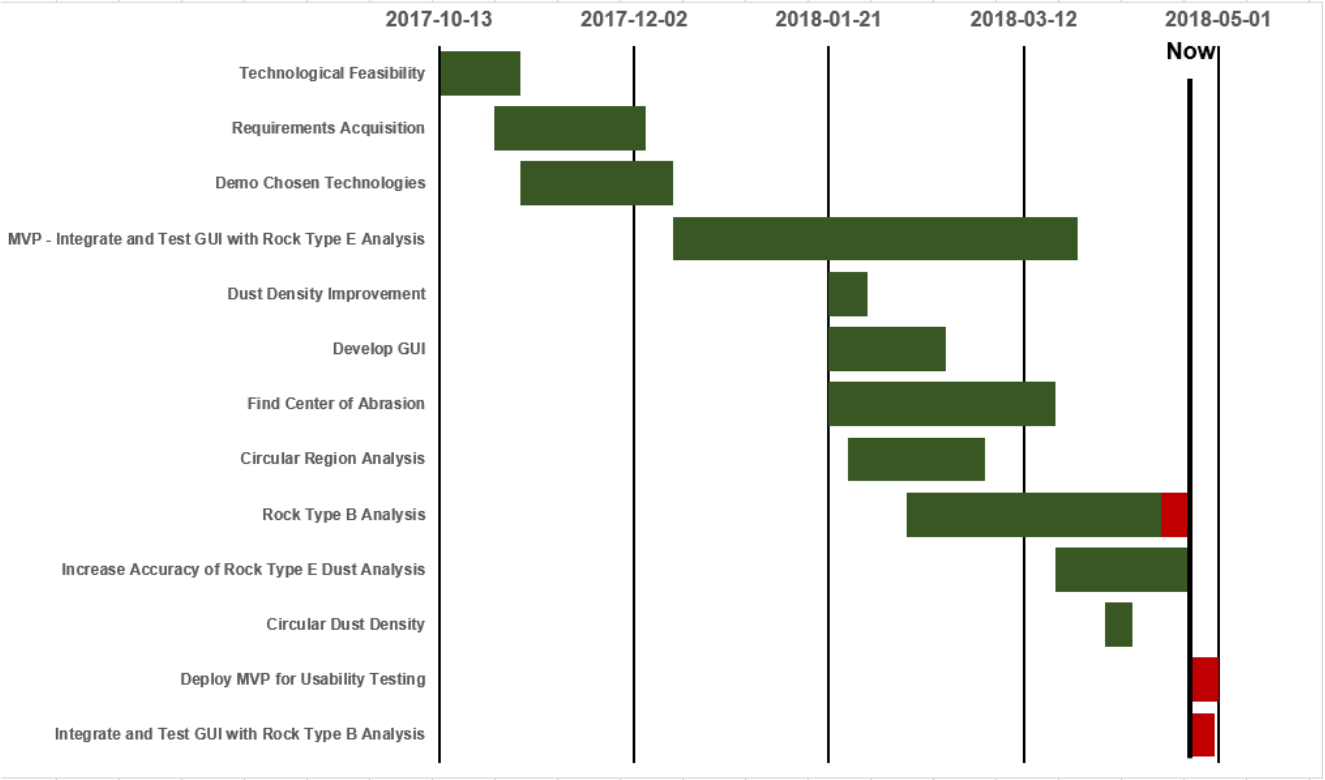
Challenges and Resolutions Cont.

- Dark areas in abrasion image
  - Some abrasion images have shadows in the hole and this messes up the accuracy of our analysis tools
  - Resolution: Tweak color range to include darker regions

Analyzed

Original

Schedule


2017-10-13
2017-12-02
2018-01-21
2018-03-12
2018-05-01
Now
Technological Feasibility
Requirements Acquisition
Demo Chosen Technologies
MVP - Integrate and Test GUI with Rock Type E Analysis
Dust Density Improvement
Develop GUI
Find Center of Abrasion
Circular Region Analysis
Rock Type B Analysis
Increase Accuracy of Rock Type E Dust Analysis
Circular Dust Density
Deploy MVP for Usability Testing
Integrate and Test GUI with Rock Type B Analysis
Legend
Progress
Task Duration

Testing Plan: What we are testing

- Image Processing/Analysis
  - Use of unit tests to enforce the correctness of our image processing, and analysis algorithms
  - Test image processing algorithms for producing a dust mask matching JPL’s analysis
- Module Communication
  - Testing that all modules are integrated correctly using integration tests
  - Confirms that our system is able pipe data between modules with the desired result
- GUI Testing
  - Testing the GUI and get user feedback from our client on displaying final analysis
  - Develop a more robust and user friendly GUI

Testing Plan: How we'll respond to our testing

- Image Processing/Analysis
  - Iterative adjustment of Processing/Analysis algorithms to better match JPL's analysis
  - Will be a continuous process and adjusted as the need arises
- Module Communication
  - Errors in communication between modules will be handled as they arise
  - Adjustments will be made to ensure correct data is being communicated between modules
- GUI Testing
  - Will be sent to JPL for a period of testing and comeback closer to the end of the semester
  - All GUI modifications will be done in a week long period

Testing Plan: How we are testing

- Pytest Testing Framework
  - Script style unit and integration testing for all necessary modules
  - Tests can be parameterized and minimize number of tests that need to be written
  - Also handles code coverage
  - Example
    - Given image is run through an analysis function
    - Is then compared against values that we are anticipating from the analysis
- JPL Client Testing
  - Software will be sent to JPL for user testing with a questionnaire for feedback

Future Work

- Laid groundwork for analysis for more rock types
  - Created with modularity and extensibility in mind.
  - JPL can implement other computer vision algorithms to analyze dust in other rock types
- Parallelize analysis
- Improve accuracy of analysis for rock types

Conclusion

- Client and Problem
- Solution Vision
  - Take in a batch of images
  - Automatically apply computer vision algorithms to detect dust
  - JPL can then run multiple tests in a single vacuum chamber pump down session
  - Get feedback on how effective their gas Dust Removal Tool is
- Overview of:
  - Requirements/Specs
  - Architecture
  - Implementation
  - Product
  - Challenges and Resolutions
  - Testing Plan
- Project Impact

Sources

https://mars.nasa.gov/programmissions/missions/present/2003/

https://en.wikipedia.org/wiki/Mars_Pathfinder

https://www.jpl.nasa.gov

https://mars.nasa.gov/mars2020/mission/rover/