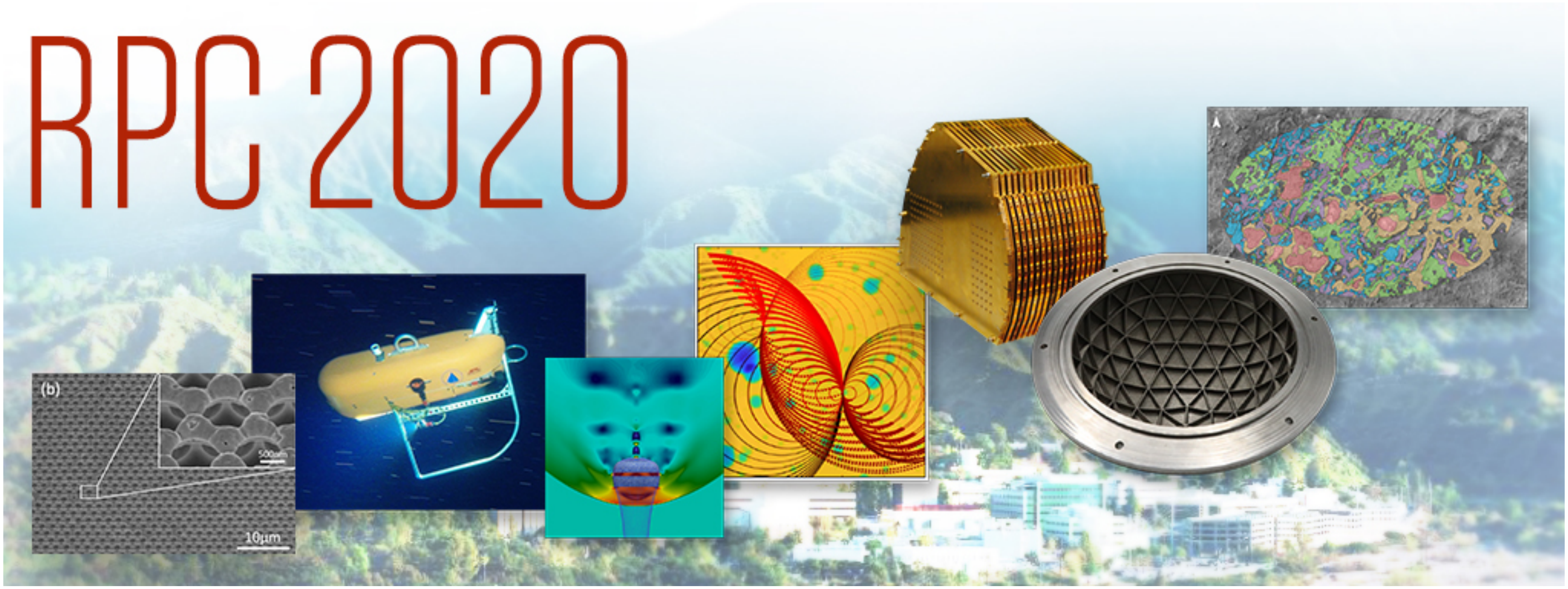


Virtual Research Presentation Conference

Enhancing JPL's Mission Science Planning & Data Discovery Capabilities with Machine Learning

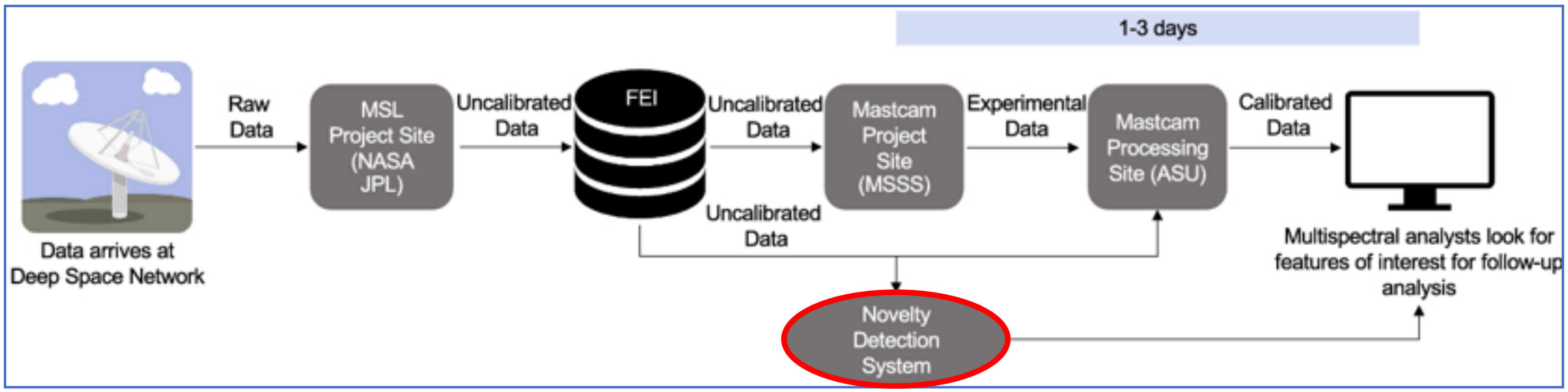
Principal Investigator: Kiri Wagstaff (398)
Co-Is: James F. Bell III (Arizona State University), Heni Ben Amor (Arizona State University), Paul Horton (Arizona State University), and Michael McAuley (398)
Program: SURP
Assigned Presentation #RPC-112

Jet Propulsion Laboratory
California Institute of Technology

Introduction

Our goal was to collaborate with Arizona State University to develop software technologies that leverage machine learning to enhance JPL's mission planning and data discovery capabilities. We focused on the infusion of methods for novelty detection in data returned by planetary missions into (1) Mars rover operational planning and (2) public access to image archives through the Planetary Data System.

These methods can help mission science planners prioritize their time by quickly directing attention to potential discoveries that may benefit from follow-up observations. The PDS deployment can increase public interest and awareness of the rich diversity of content in NASA's planetary image collections.



Modified from Kerner et al. (2020)

Student research support

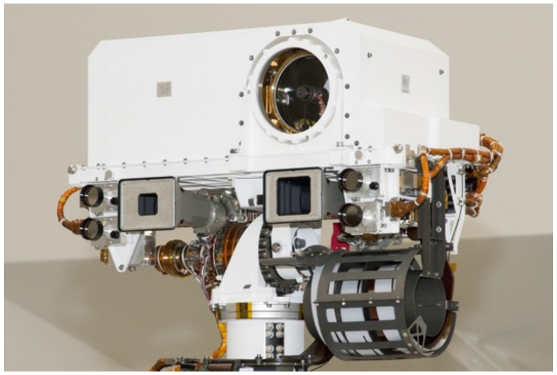
An important part of SURP projects is the support of student research and progress. This project benefited greatly from the work of Paul Horton, a graduate student at Arizona State University.

Paul's outstanding accomplishments this year include:

- Maturation of the novelty detection method implementations
- Led open-source release of algorithms with Docker containers (code and data)
- Deployed novelty detection methods for:
  - MSL operational planning setting (downlink)
  - Planetary Data System image archives
- Led or contributed to multiple publications
- Won a NASA Space Technology Graduate Research Opportunities Fellowship

Paul Horton (ASU)

Problem Description



Context

- Desire to reduce mission planning time
- Tools that direct attention to most novel or unusual observations can help prioritize options

State of the art

- Most image novelty detection methods assume grayscale or RGB images
- Multispectral novelty detection has been applied offline to low-resolution images to assess strengths/weaknesses
  - Some methods most sensitive to *structural* novelty while others sensitive to *spectral* novelty (Kerner et al., 2020)

Relevance to NASA and JPL

- Help streamline target prioritization in rover planning operations
- Help increase competitiveness of future mission and instrument proposals
- Increase public access to and awareness of rich diversity of NASA's planetary image collections
- Accelerate rate of new discoveries in remote planetary exploration (reduce chance of missing novel observation)

Methodology

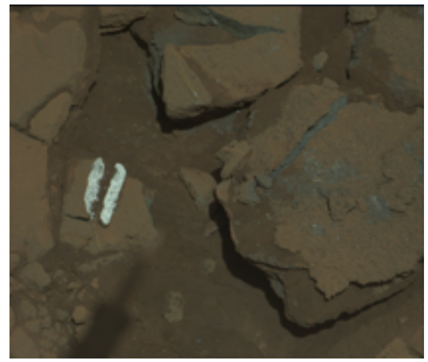
Multispectral image novelty detection methods

- Reed Xiaoli (RX) [2]
- Principal component analysis (PCA)
- Convolutional autoencoder
- Generative adversarial network (GAN) [1]

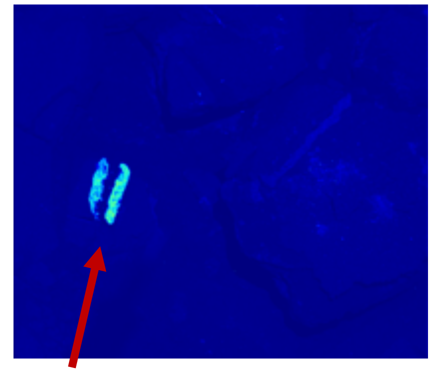
Innovation

- Open-source release of algorithms and data for public availability
- Development of novelty-based product ranking for MSL Mastcam operational planning
- Deployment of novelty-based scoring for large PDS image archives
- Application to other multispectral instruments

Mastcam image (6 bands)



RX novelty

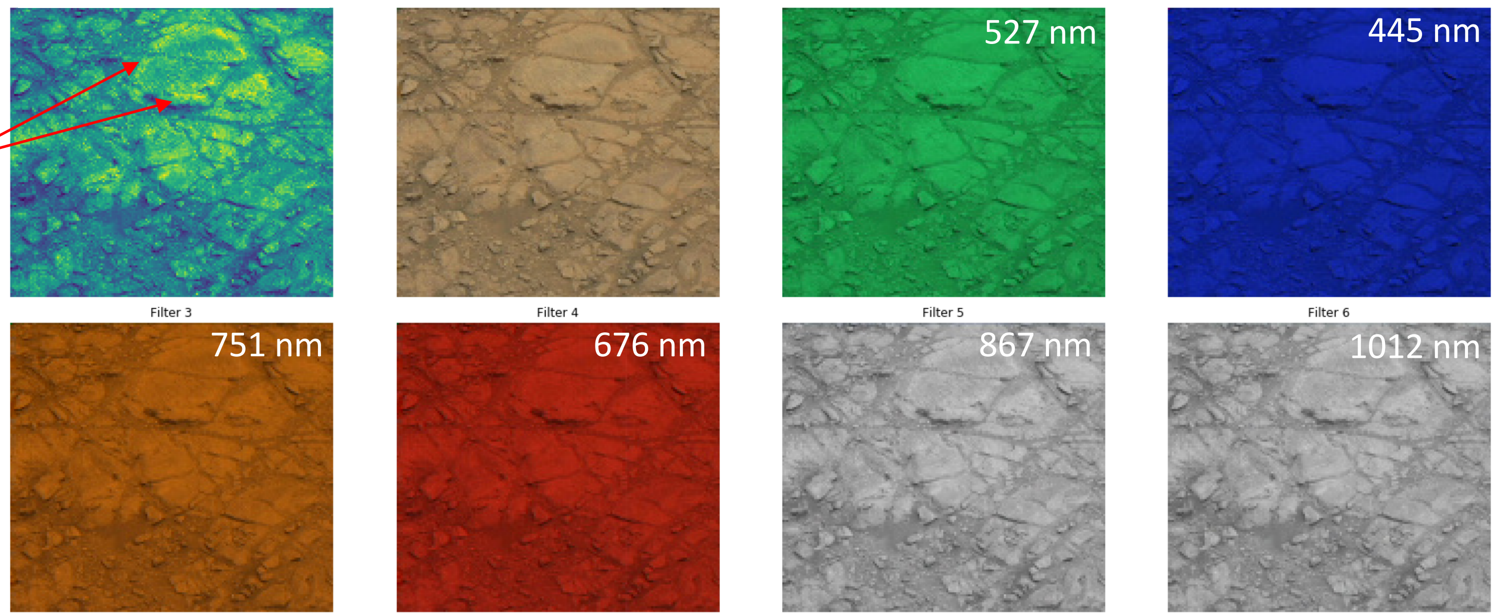


Max. novelty: broken rock with exposed fresh face

Accepted for IEEE Aerospace Conference (Horton et al. 2021)

Results: Novel Mastcam observations

Highlighted pixels indicate unusual spectral features near edge of rock



Highlighted pixels are evident in bands 5 and 6 but not in RGB; could easily be overlooked

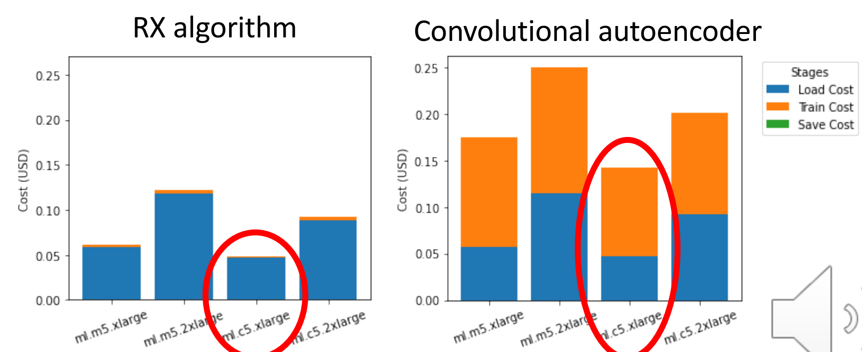
Results: Deployment to the Planetary Data System

- Novelty analysis algorithms published as open-source toolbox
  - https://github.com/JPLMLIA/mastcam-noveltydet
- Algorithms deployed on Amazon Web Services as a queryable endpoint
  - Specify instrument, baseline data set, and new image to analyze; receive novelty score for that image

Top 5 most novel Mastcam images

Bottom 5 least novel Mastcam images

- Benchmarking important for deployment in support of the PDS Imaging Atlas and real-time queries
- Finding: novelty analysis algorithms can be be used with low time and cost even at scale
  - CAE is more costly than RX
  - "compute-optimized" nodes are best for both algorithms
- Submitted to Fall AGU (Horton et al. 2020)



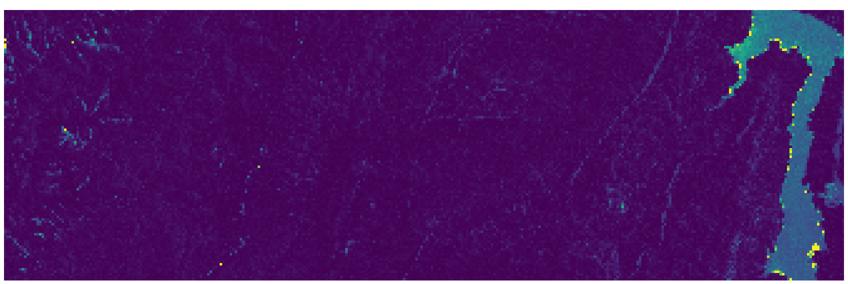
"compute-optimized" nodes are best choice

Results: Application to multispectral Earth observations

- Train new model using observations (22M pixels) of Australia by the PlanetScope imaging satellites in 2019 (before major fires)
  - 4-band data includes red, green, blue, and near infrared wavelengths
- Apply to 10 observations of a new area in Australia (Blue Mountains National Park)
- Significance: same algorithms can operate on different imaging targets and instruments

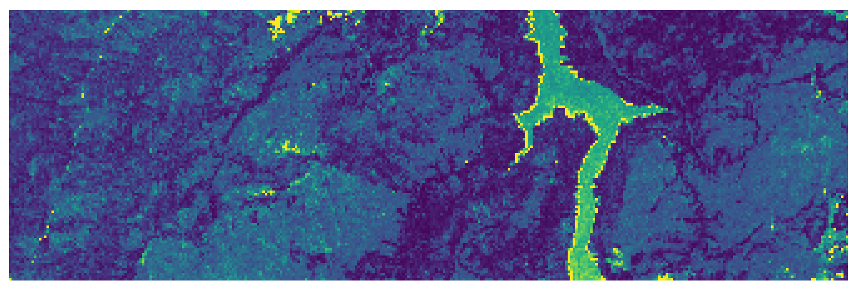
Low novelty scores before fires

Blue Mountain 2019 Mean Score: 0.871791



High novelty scores after fires (lack of vegetation)

Blue Mountain 2020 Mean Score: 4.877154



Conclusions and Future Work

- Successful collaboration with Arizona State University faculty and graduate student Paul Horton
- Application of novelty detection methods to:
  - Analyze MSL Mastcam downlinked images and identify most interesting for deeper investigation
  - Planetary Data System to accelerate analysis of large image archives and better understand diversity of collections
- Extension to other multispectral images (PlanetScope Earth observations)

Acknowledgments:

- We thank the Mastcam instrument team and the broader Mars Science Laboratory team, particularly Ernest Cisneros (ASU) and Samantha Jacob (ASU) for their input into the novelty analysis interface. We also thank Hannah Kerner for her continued input and guidance on the work as well as the Planetary Data System Imaging Node, especially Kevin Grimes, for supporting this work and providing mentorship for the PDS integration.

Publications and References

Publications

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[1] Ian Goodfellow, Jean Pouget-Abadie, Mehdi Mirza, Bing Xu, David Warde-Farley, Sherjil Ozair, Aaron Courville, and Yoshua Bengio, "Generative adversarial nets," *Proceedings of the 27th International Conference on Neural Information Processing Systems*, 2014.

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