Machine Learning Data Analyses for Asteroid and Micrometeorite Samples: Correlating Features of Asteroid Ryugu and Unmelted Micrometeorites

Lewis J. Pinault[1,2], Hajime Yano[3], Matthias van Ginneken[4], Matthew J. Genge[5,6], Natasha V. Almeida[6], Penelope J. Wozniakiewicz[4,6] and Luigi Folco[7]

[1]*School of Natural Sciences, Birkbeck College, Gower Street, London WC1E 7HX, UK*

[2]*Centre for Planetary Sciences at University College London/Birkbeck, Gower Street, London, 61E 6BT, United Kingdom*

[3]*Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 3-1-1 Yoshinodai, Chuo-ku, Sagamihara, Kanagawa252-5210 Japan*

[4]*Centre for Astrophysics and Planetary Science, Department of Physics and Astronomy, University of Kent, Canterbury, UK*

[5]*Department of Earth Science and Engineering, Imperial College London, London, UK*

[6]*Planetary Materials Group, Natural History Museum, London, UK*

[7]*Università di Pisa, UNIPI · Department of Earth Science, Italy*

We have built on previous work where we have developed and trained Machine Learning (ML) convolutional network models on aerogel-captured samples of the Tanpopo [1] missions onboard the International Space Station using new camera, recording, and processing techniques that greatly speed and automate their identification and classification. We now apply these techniques to SEM images of asteroid Ryugu samples collected by the Hayabusa2 mission. Our YOLO-ET (You Only Look Once – ExtraTerrestrial) model moved beyond datasets that have already been laboriously centred, focused, scaled, imaged, and classified to various types by human researchers [2] to open the door to automated transits by microscope across the Tanpopo aerogel to have the images fed directly into our core ML Object Detection programme. The YOLO-ET model has now been tuned to use its object detection/localisation capabilities to automatically draw bounding boxes around objects of interest in SEM images of the Ryugu A0180 sample, and to automatically run a confidence prediction of which classification of the types it might be, displayed both on the image and as a searchable table [3].

Drawing on hundreds of scans of the Ryugu A0180 sample, our model has been trained on 2D segmented images [4] whose cross-sections helped reveal characteristic micro-features within the sample such as voids, cracks, and micro-chondrules of particular interest. This demonstrates firstly advantages over human-eye examination of void evidence. Work by the team on 3D distribution in cross-section allowed re-integration of the images to reveal the voids in full dimension, and now the manual process of identifying and classifying evidence of voids in cross-section has been transformed for ML identification, classification, and reintegration using the methods we have developed.

The data gained by manual imaging of A0180 has formed a robust training data set for applying to more porous and aggregate samples such as unmelted micrometeorites collected in the terrestrial environment. As a demonstration, we have applied our YOLO-ET model trained on classified features detected in the SEM images of the Ryugu A0180 sample to SEM images at the same scales as selected unmelted micrometeorites from the Trans-Antarctic Mountains collection [5] as well as others, and found high confidence levels of automatic detection, localisation, and classification of similar features, constituting a first practical comparison of characteristic micro-structures with the wider suite of micrometeorite collections using Machine Learning and Computer Vision. We thus demonstrate that it is now possible for ML modelling to: (i) newly constrain carbonaceous asteroid origins like Ryugu for unmelted micrometeorites; (ii) connect evidence found in the Ryugu samples to the potential underrepresentation of particular meteoritic constituents in terrestrial collections; and (iii) begin large scale classifications of micrometeorites collections around the world.

References

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