Machine Learning Data Analyses for Asteroid and Micrometeorite Samples

Lewis Pinault[1] and Hajime Yano[2]
[1]*School of Natural Sciences, Birkbeck College, Gower Street, London WC1E 7HX, United Kingdom*
[2] *Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 3-1-1 Yoshinodai, Chuo-ku, Sagamihara, Kanagawa 252-5210 Japan*

We have developed and trained Machine Learning (ML) convolutional network models on aerogel-captured meteoroid 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. This technique moves beyond datasets that have already been laboriously centred, focused, scaled, imaged, and classified to various types by human researchers, and builds on prior systems [2] to open the door to automated transits by microscope across the Tanpopo aerogel panels at approximately 500x500 pixel increments, at different focal lengths, with images then fed directly into core ML Object Detection programme. The programme then uses its object detection/localisation capabilities to automatically draw bounding boxes around the object or objects of interest in each image, 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].

The time-and-manpower gains that can be affected by ML became clear with its further application to the Ryugu A0180 sample. Hundreds of nano-CT scans were conducted to create segmented images [4] whose cross-sections helped reveal characteristic micro-features within the sample such as voids, cracks, and micro-chondrules of particular interest. For an example, human-eye examination of void evidence and 3D distribution in cross-section allowed re-integration of the images to reveal the voids in full dimension. This manual process of identifying and classifying evidence of voids in cross-section is ripe for ML identification, classification, and reintegration using the methods we have developed. Moreover, the data gained by manual imaging of A0180 now forms a robust training data set for applying to more porous and aggregate samples such as unmelted micrometeorites collected in the terrestrial environment.

Thus, 3D optical images, nano-CT data, and external and internal SEM images of Ryugu asteroid samples returned by Hayabusa2 can be archived at international research institutions to create further training data for searching the diversity among different groups of asteroid samples and for practically comparing characteristic micro-structures with the wider suite of micrometeorite collections. In this manner, it may also be possible for the ML modelling to connect evidence found in the Ryugu samples to the potential underrepresentation of particular meteoritic constituents in terrestrial collections.

References

[1] A. Yamagishi, S. Yokobori, K. Kobayashi, H. Mita, H. Yabuta, M. Tabata, M. Higashide, and H. Yano (2021) Scientific Targets of Tanpopo: Astrobiology Exposure and Micrometeoroid Capture Experiments at the Japanese Experiment Module Exposed Facility of the International Space Station, Astrobiology, p1451-1460. http://doi.org/10.1089/ast.2020.2426
[2] S. Sasaki, J. Imani, and H. Yano (2019) Design, Fabrication and Evaluation of an Aerogel Processor CLOXS for the Astrobiology Mission Tanpopo, Biological Sciences in Space, 33, p. 7-11.
[3] L. Pinault, K. Okudaira, H. Kiryu, I. Crawford, and H. Yano (2023, in preparation) Machine Learning Programme for Extraterrestrial Microparticles Using a Custom Machine Learning Model with Mobile Computer Vision and Processing Systems, *Journal title?*
[4] M.J. Genge, N. Almeida, M. Van Ginneken, L. Pinault, P. Wozniakiewicz, and H. Yano (2023) Ice and Liquid Water in Asteroid Ryugu – Constraints from Sample A0180, this volume.