Digital Rock Physics Analysis of Core Integrity using Deep Neural Networks and Computer Vision.

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Abstract

Core imaging and classification is an important step for generating a digital database for subsurface geology. The British Geological Survey collection contains cores from over 15,000 onshore and 8,000 offshore boreholes. Many cores are photographed at high-resolution creating an archive of over 100,000 core tray images containing between 1 m and 3 m of core per image. A crucial challenge in storage and classification of the digital data associated with these cores is the degree of damage or degradation which determines their suitability for further analysis by the scientific community. The large volume of core image data precludes manual phase segmentation and core quality determination from individuals.

In this work, we present a new method using both deep learning and computer vision to automate the process. To test the feasibility of our technique, we use a small subset of 62 core tray images, captured with 3 light spectra (Red, Green, Blue). We use pre-trained neural networks to segment the image, which is followed by traditional computer vision techniques for edge detection. We also automate the process of calculating the number of fragments and area of each fragment present in each individual core image. Finally, we present an index for core integrity based on the output of these measurements. The work-flow demonstrates that deep neural networks and computer vision can be leveraged to quantify and non-intrusively assess geophysical properties at a large scale, using only a subset of the data, with open-source packages.

This core quality index will allow users to quickly and consistently assess core condition, and in particularly degradation due to: transport, storage and previous sampling. By automating this process it is possible to quickly assess tens to hundreds of metres of core to identify areas suitable for sampling. It also provides semi quantitative information on how representative individual core samples are of bulk rock properties. This will improve integration between core analysis and other datasets, for example wireline logs.

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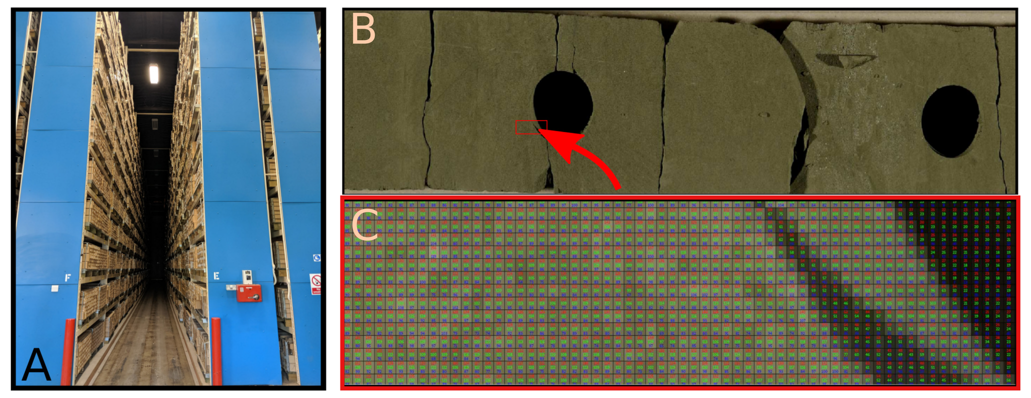
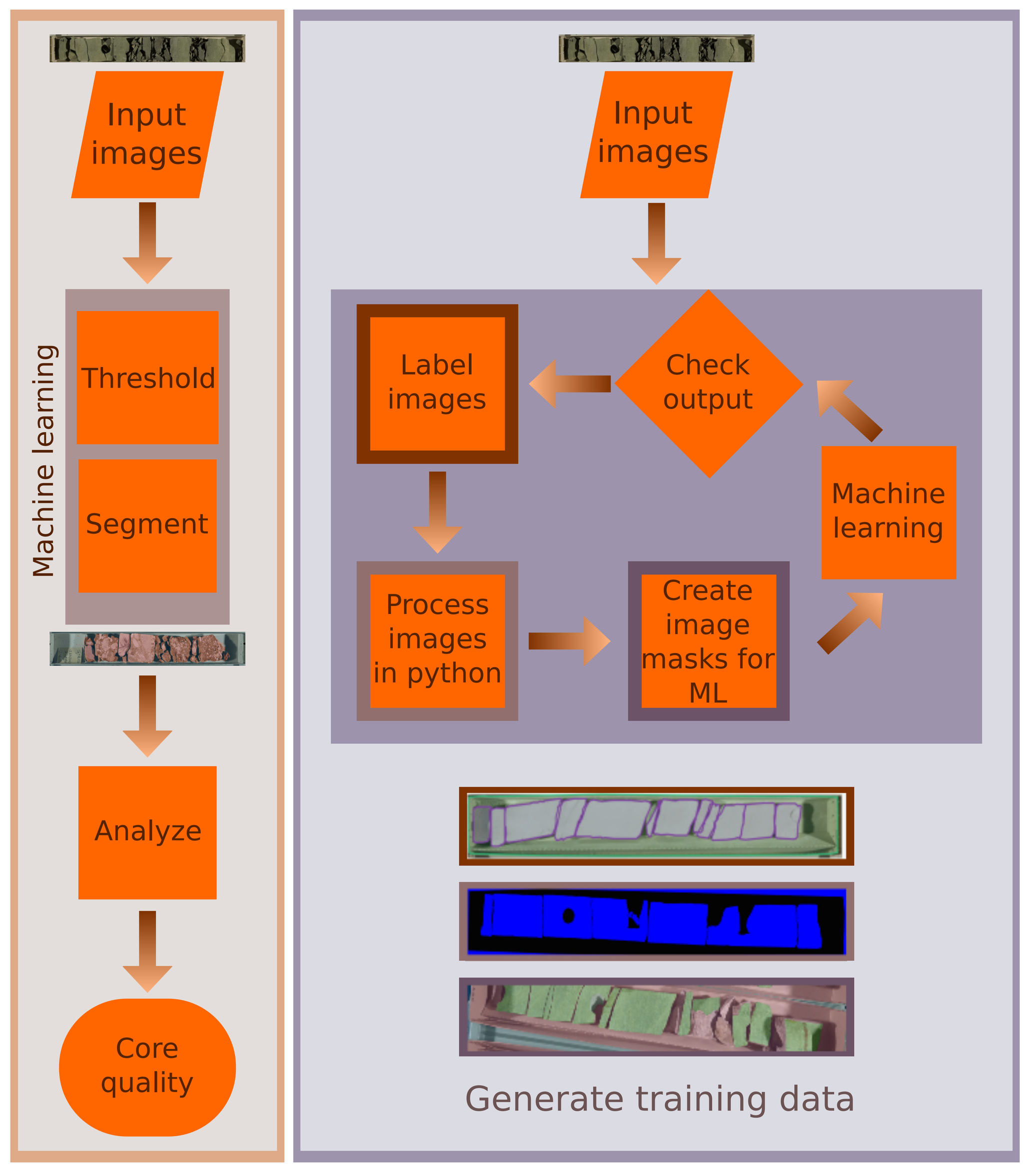
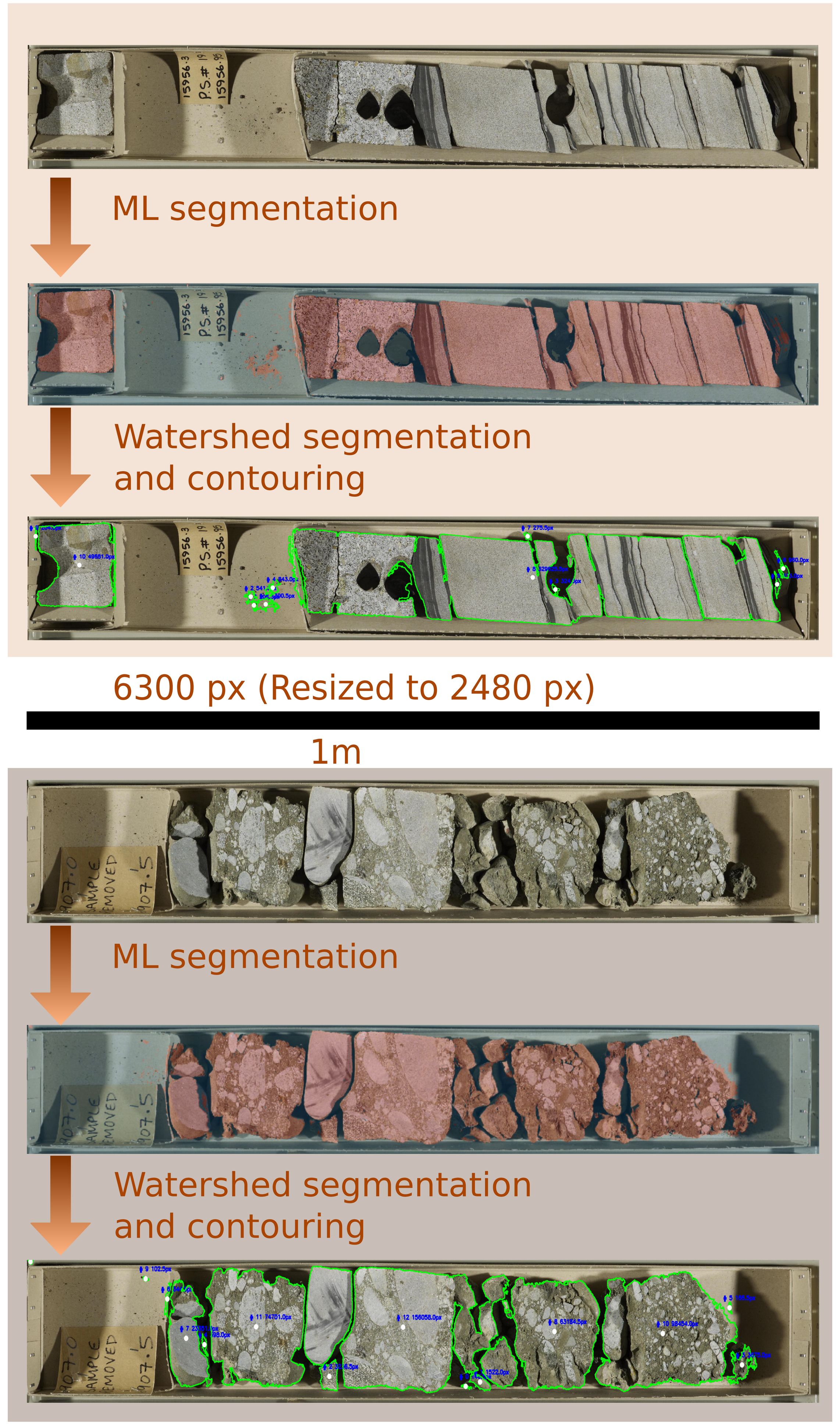
Introduction



The British Geological Survey (BGS) stores 18,000 pellets of drill cores and 80,000 trays of samples in its repository. The repository also contain 300 km of offshore core samples, which is available for academic research. Not all cores in the BGS repository are intact and suitable for further testing. A digital database consisting of information on the integrity of the cores can greatly reduce the time and effort required to locate intact cores. One method of developing this database involves analyzing existing digital images of the core trays. Due to the large volume of the core images in the BGS repository, the process of image analysis needs to be automated. In this pilot study, we address this issue by developing a machine learning (ML) based method to train an ML algorithm and process 64 images of cores from the BGS repository.

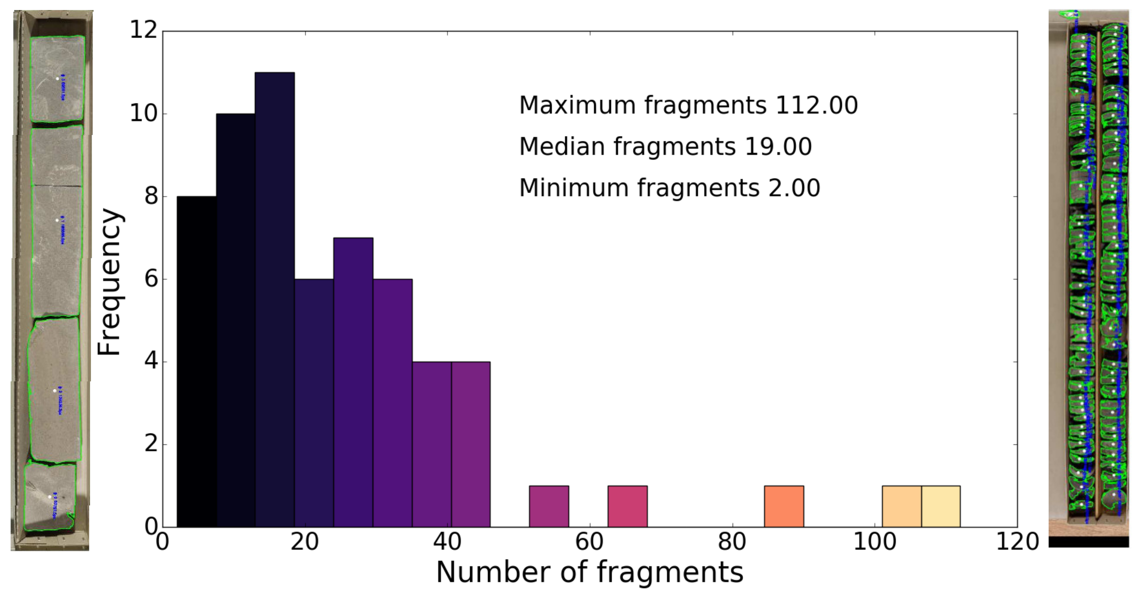
Methods

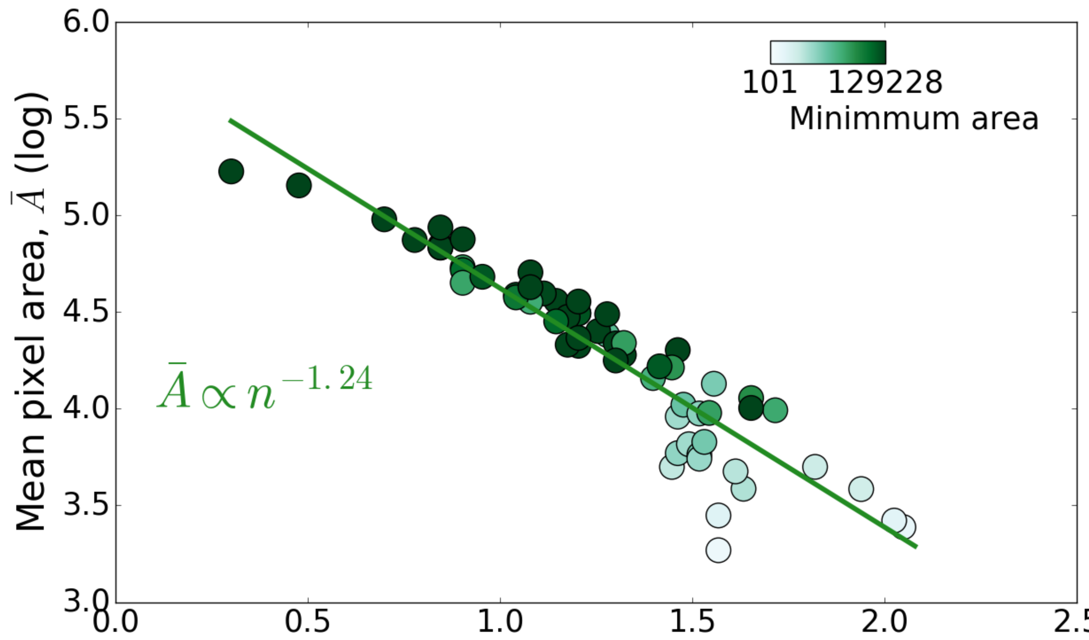


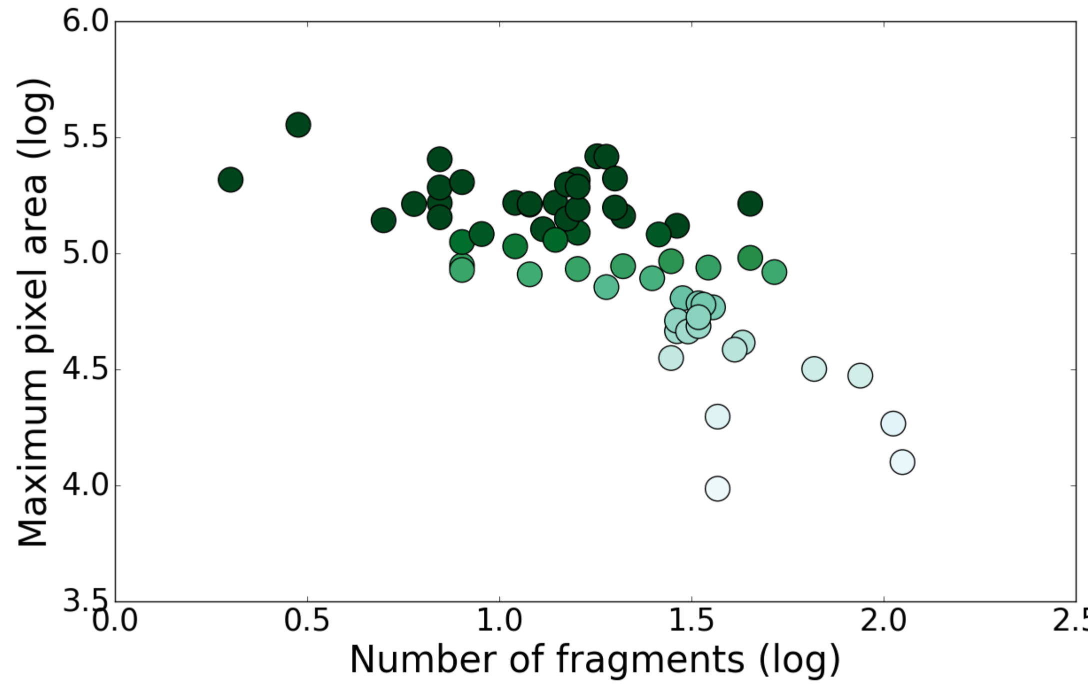


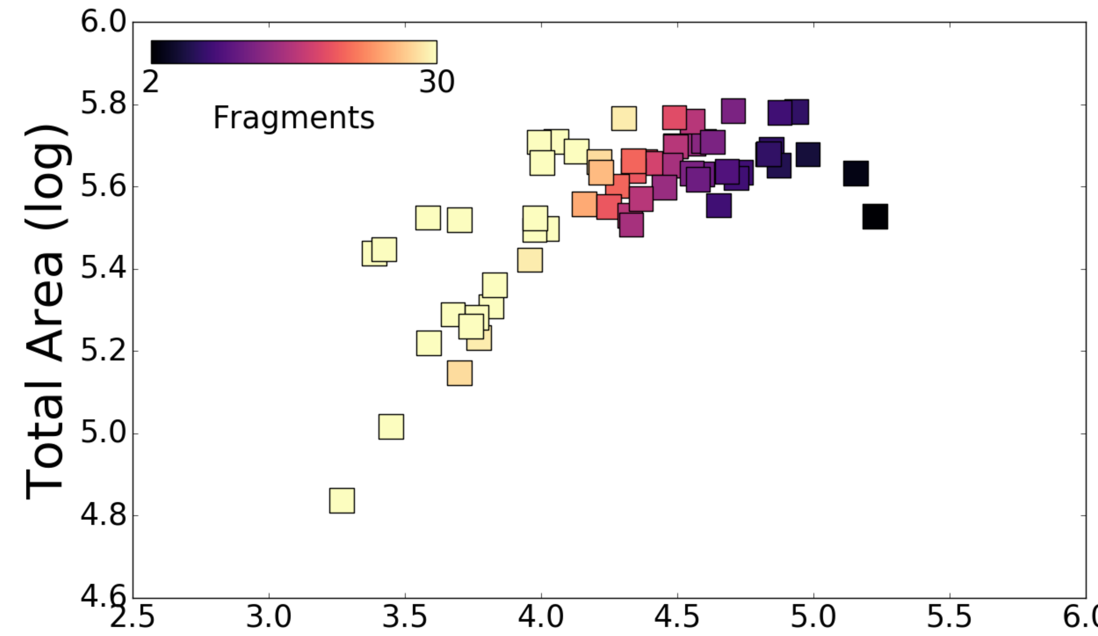
Our analysis takes place in a number of steps. First, we crop the images, processed with python, create labels, then also processed in python, both these are then combined and put into a convolutional neural network (NN, this is also supervised machine learning). The NN learns the patterns in the images, and makes predictions for unseen images. The output is then taken from the network and pushed through computer vision algorithms which give out the location and area of each piece. This can then be used for various purposes, one of which is to define core integrity, or a pipeline for facies classification.

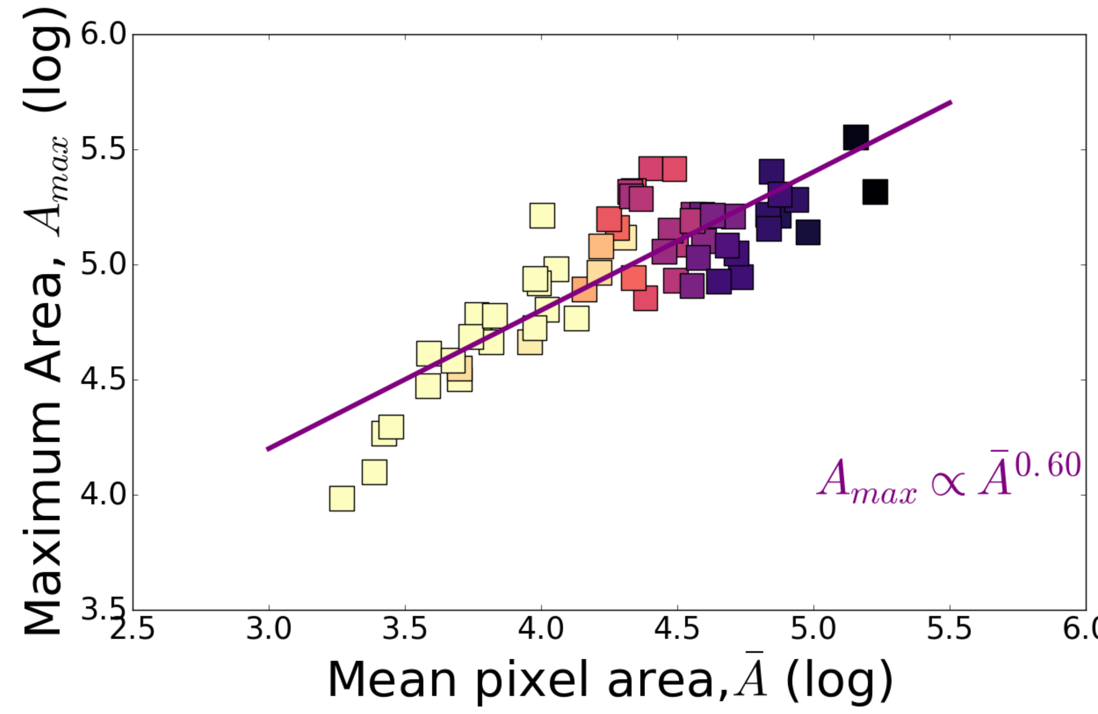
Results











Discussions

We analyzed 62 core images using the new machine learning technique. The integrity of the samples varied widely, as shown by the histogram of the number of fragments. We used a total of 40 epochs, yielding 85%–87% accuracy of segmentation. The time for each ML learning analysis was only a few seconds, substantially smaller compared to manual thresholding, segmentation, and fragment area calculation for each image. We found two important power law relations, shown in the plots, that can be further exploited to derive at a new definition of core quality index. Future studies, involving a larger training dataset, will significantly enhance the accuracy of the technique and will provide an automated method of digitally indexing core quality.