A new software collection for 3D processing of X-ray CT images

S. Chauhan[1], W. Rühaak[1], H. Anbergen[2], A. Kabdenov[2], M. Freise[2] , I. Sass[1], T. Wille[2]

[1] Institute of Applied Geosciences, Chair of Geothermal Science and Technology, Technische Universität Darmstadt
[2] APS Antriebs-, Prüf- und Steuertechnik GmbH, 37124, Rosdorf, Deutschland.
info@wille-geotechnik.com, chauhan@geo.tu-darmstadt.de

Motivation

APS GmbH is developing a new triaxial testing system for methane hydrate research. Embedded in the latest research project "SUGAR 3" a high-pressure triaxial system is equipped with high-resolution X-ray computer tomography (XCT). In order to get most accurate results, a new software solution was developed that analyses objectively obtained XCT-images. This software solution was developed in cooperation between APS and the Institute of Applied Geothermal Science of the Technische Universität Darmstadt.

A new software is proposed, which is based on machine learning (ML) techniques, for the 2D/3D visualization of XCT data. The segmentation and classification of different phases are based on feature vector selection and is performed using unsupervised, supervised, and ensemble ML techniques [1][2]. Thereafter, using these segmented images, relative porosities and trends in pore size distribution can be computed. The computational performance is optimized using correlation-based feature vector selection. Furthermore, accuracies of ML techniques are accessed based on entropy, purity, and receiver operation characteristics.

Work Flow

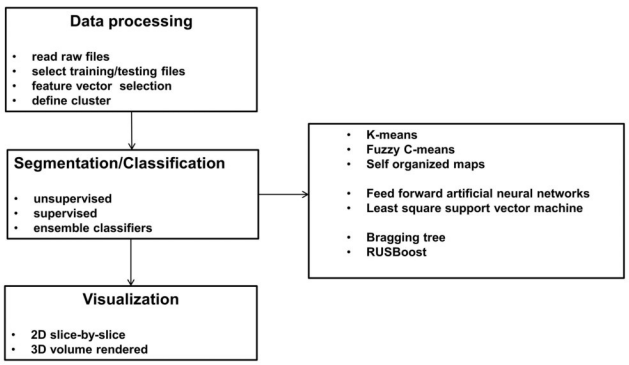
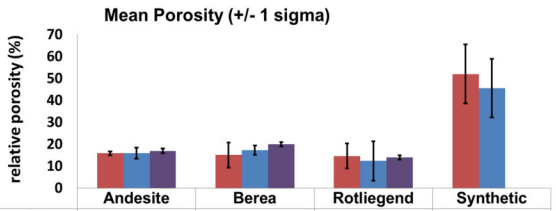


Figure 1: Schematic illustration of our proposed method.

Porosity



	Andesite	Berea	Rotliegend	Synthetic
Supervised + Ensemble classfiers	16	15	15	52
Unsupervised	16	17	12	46
Laboratory measurements	17	20	14	

Figure 4: Mean porosity value obtained using supervised, ensemble classifiers and unsupervised machine learning techniques.

Porosity was computed by indexing out pore phase voxels divided by total no. of matrix voxels multiplied by hundred. The porosity values were compared with laboratory measurements (GeoPyc pycnometer (Micromeritics Instrument Corporation Norcross, GA, USA), which showed very good agreement within ± 2 %.

Pore Size Distribution

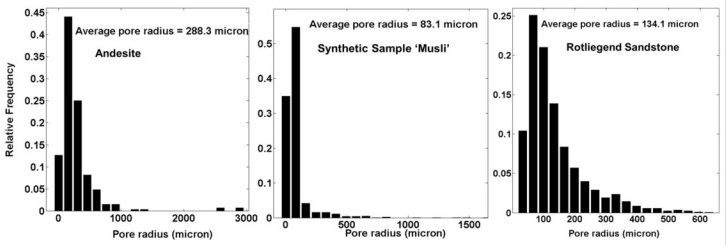


Figure 5: Pore size distribution obtained from the segmented images using modified watershed techniques [3].

Conclusions

Machine learning (ML) techniques are a promising alternative for phase segmentation of XCT data. Porosity, pore size distribution and volume fraction analysis can be retrieved with suitable accuracy. Porosity values obtained using ML techniques for volcanic rock, sandstones are in good agreement to laboratory measurement. In terms of computation speed K-means is the fastest among other ML techniques and Least Square Support Vector Machine (LS-SVM) is the most accurate. We recommend to test different setting and careful feature vector selection for best trade-off between computational speed and accuracy.

Acknowledgment

This work is funded within the framework of the SUGAR (Submarine Gashydrat Ressourcen) III project by the Federal Ministry of Education and Research (BMBF grant no. 03SX381H) and also partly supported by the DFG in the framework of the Excellence Initiative, Darmstadt Graduate School of Excellence Energy Science and Engineering (GSC 1070). The sole responsibility for the contents lies with the authors.

We thank Michael Kersten, Frieder Enzmann and his group at the institute for Geoscience Johannes Gutenberg Universität Mainz for the high resolution X-ray tomography measurements of Andesite and Rotliegend sandstone. We thank Phillip Mielke and Achim Aretz for the field work and collection of rock samples. Hieko Andrä and her team at Fraunhofer ITWM Germany for making synchrotron dataset of Berea sandstone freely available online.

Data Analysis

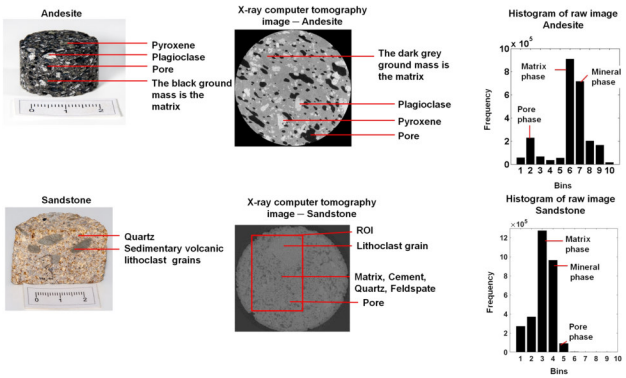


Figure 2: The top panel shows the Andesite and Rotliegend sandstone rocks used for XCT measurements. Middle panel shows the raw images of Andesite (16bit), Rotliegend sandstone (16 bit), Mineral composition of Andesite and Rotliegend sandstone was determined from thin sections using polarized microscope. Bottom panel shows, histogram plot of the respective samples.

Image Segmentation

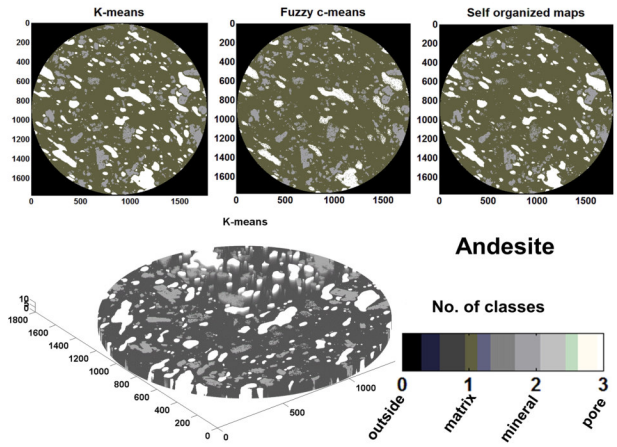


Figure 3: 2D segmented images and volume rendered plot of Andesite samples using unsupervised Machine learning technique

Validation

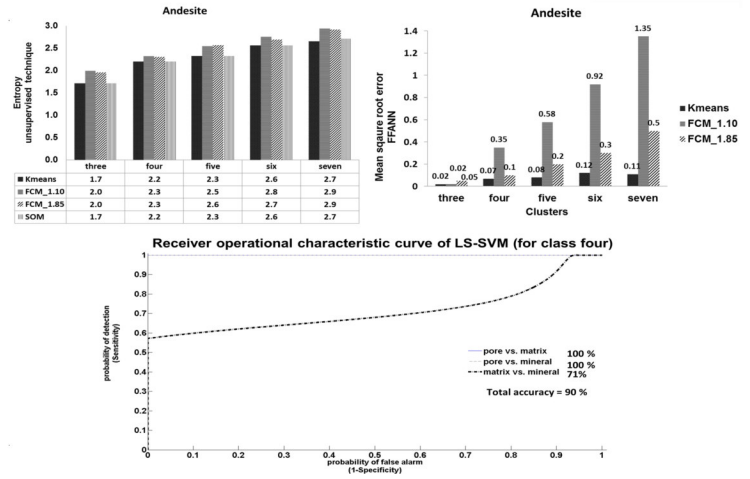


Figure 6: top left show the entropy values obtained for Andesite sample segmented using unsupervised techniques. Top right show mean square root error obtained for Andesite sample classified using feed forward artificial neural network (FFANN). The FFANN was trained using k-means, Fuzzy C-means with membership function [1.10, 1.85]. The bottom panel shows the receiver operational characteristics of LS-SVM for classified class four.

References

[1] Chauhan, S., Rühaak, W., Khan, F., Enzmann, F., Mielke, P., Kersten, M., & Sass, I. (2016). Processing of rock core microtomography images: Using seven different machine learning algorithms. Computers & Geosciences, 86, 120-128. doi: 10.1016/j.cageo.2015.10.013.

[2] Chauhan, S., Rühaak, W., Anbergen, H., Kabdenov, A., Freise, M., Wille, T. & Sass, I (2016). Phase Segmentation of X-Ray Computer Tomography Rock Images using Machine Learning Techniques: an Accuracy and Performance Study. Solid Earth, 7, 1125-1139. doi:10.5194/se-7-1125-2016.

[3] Rabbani, A., Jamshidi, S., Salehi, S. (2014). An automated simple algorithm for realistic pore network extraction from micro-tomography Images, Journal of Petroleum Science and Engineering, 123, 164-171.

Contact:
Swarup Chauhan
Technische Universität Darmstadt
Institut für Angewandte Geowissenschaften
Schnittspahnstraße 9
D-64287 Darmstadt
Germany
E-mail: chauhan@geo.tu-darmstadt.de