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Foraminiferal sorting and identification: preliminary results of a test phase

Marit-Solveig Seidenkrantz[1], Claus Melvad[2], Kim Bjerge[2], Peter Ahrendt[2], Emiel J. Broeders[2], Anders O. B. Christensen[2], Mikkel Førrisdahl[2], Troels Poulsen[2], and Esben Skov[2]

[1]Aarhus University, Department of Geosciences, Aarhus, Denmark (mss@geo.au.dk)

[2]Aarhus University, Aarhus University School of Engineering, Aarhus, Denmark

One of the best methods for studying past climate variability is the analyses of microfossils in sediment cores, especially foraminifera. However, this is highly laborious and time-consuming work. Consequently, several independent endeavors are currently underway with the aim of to automate this procedure, each testing different techniques. Here, we present preliminary results of one of these endeavors that focus on benthic foraminifera from arctic and temperate regions. The study is based on ongoing student projects carried out in collaboration between engineers and geologists. We combine robotics, imaging and machine learning.

The project is divided into three stages, with stage 1 and 2 currently ongoing: 1) Robotic separation of foraminiferal specimens from sediment particles, 2) Species classification algorithm based on Convolutional Neural Networks (CNN) including creation of training material. 3) System verification comparing analyses carried out by the automated system and a foraminiferal specialist on the same dataset. Phase 3 has not yet commenced, but initial results of 1 and 2 are available. In time, we hope to be able to build up a database of about 100 different foraminiferal species, which will cover the main assemblages of the coastal regions of the Arctic and Atlantic cold temperate regions.

For separating and picking of specimens (1) we have evaluated two different methods using a custom made xyz-platform or a robotic arm. Based on this, it seems that moving the specimens with a robotic arm will work well, but the price of such a robotic arm makes this solution less practical. In contrast, the combination of separating the specimens through shaking the sample in a tray and picking specimens for photographing and analyses using a suction system, with a custom made xyz-platform, is the best solution when considering quality, speed and price. Subsequently, the picked foraminifera/grains are delivered automatically to a digital microscopy system and photographed. So far focus on this part of the process has been developing a precise system for moving and picking, and in the future, we will work towards being able to handle particles of highly variable size in the same sample as well as increasing the speed of the picking and photographing process.

For foraminiferal identification (2), parts of the labeling process have been automated using the Django (Python) framework and Amazon Web Services. Also, a number of imaging experiments

have been investigated and several Convolutional Neural Network (CNN) algorithms are being developed and tested. In this first test, we include three different benthic foraminiferal species, with very distinct morphologies, as well as various types of clastic grains in approximately the same size fraction as the foraminiferal individuals. In this initial test case only relatively few specimens were included in the database (Ammonia batava - 168 specimens, Elphidium williamsoni - 168 specimens and Quinqueloculina seminulum specimens - 168 specimens as well as 449 clastic grains). Using a customized CNN algorithm, the separation of foraminifera from mineral grains and foraminiferal species identification could be carried out respectively with a precision, recall and F1-score of 94% and 91%.