AMOR – A ROBOT FOR AUTOMATED IMAGING OF MICROFOSSILS

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1. Abstract

An imaging robot called AMOR (from Automated Measurement system for shell mORphology) was built for more efficient morphometric data collection from isolated microfossils with a PC-based imaging system.

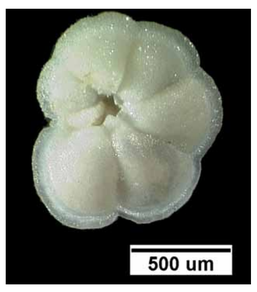
AMOR consits of a motorized four-axis tilting- and gliding stage for automatic positioning under a binocular microscope equipped with a digital video camera. The microscope is driven by a motorfocus and a motorized zoom. All components are controlled by a software written in LabView 8.5.

The system allows to automatically position series of planktonic foraminifera, that are mounted in a faunal slide under a binocular microscope, in perfect keel or umbilical/spiral view, and then to collect images for further digital image processing.

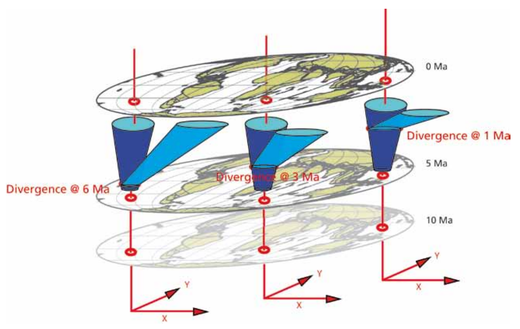
2. Introduction

Statistically robust morphometric information about the intra- or interspecific variability of microfossils requires often measurement of thousands of specimens. The manual collection of such data is cumbersome and bears the risk of errors due to imprecise positioning of the specimens under the microscope. In order to improve efficiency and precision of digital image collection from planktonic foraminifera AMOR was developed in collaboration with students and engineers from the Applied University of Northwestern Switzerland (Knappertsbusch et al., in press).

Digital images are used to investigate the biogeography of morpho logical evolution of menardiform globorotalids (concept of „evolutionary prospection“). This foraminiferal group exhibits great morphological variability during the Neogene.



Globorotalia menardii in umbilical view



Concept of „Evolutionary prospection“ to resolve questions about the mode and biogeography of morphological speciation in the fossil record.

3. Basic operations:

Imaging specimens with AMOR requires pre-oriented specimens in keel- or umbilical/spiral views in a multicellular faunal slide. After initialization steps AMOR first moves to the center of a particular field, autofocuses, tilts the slide in x- and y direction until the specimen stands perfectly upright in keel position or is perfectly horizontal when spiral/umbilical position was selected. After automatic image rotation for perfect “north-to-south” orientation of the shell the best zoom for final imaging is sought. After auto-focusing a tiff image is saved to disc and the stage moves on to the next specimen repeating the cycle until the last specimen has been imaged.

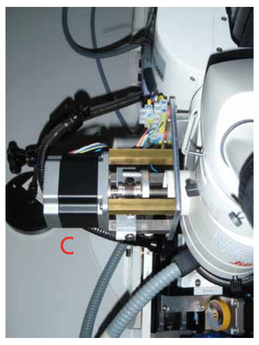
The magnification for every image is recorded for later conversion of peripheral pixels to micrometers. A slide-calibration routine is implemented for usage of different types of faunal slides.

The user can choose between “single-specimen” mode and „automated“ mode to orientate specimens individually or to automatically process the entire slide. In the „automated“ mode each field can be flaged for inclusion or exclusion into the process.

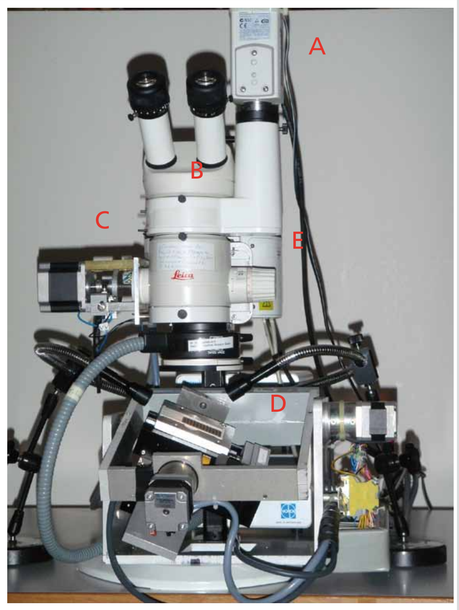
The images obtained are batch-processed using separate programs for outline extraction, conversion of pixels to micrometers, data-reduction, normalization, extraction of morphometric parameters, polar fourier analysis or derivation of simple statistics (Knappertsbusch, 2004).

4. Hardware

Digital video camera (A)
Leica MZ6 Binocular (B)
Motorzoom (C)
4-Axis motor stage (D)
Focus motor from from Leica (E)
Cross polarized light (F)
Pentium PC (not shown)

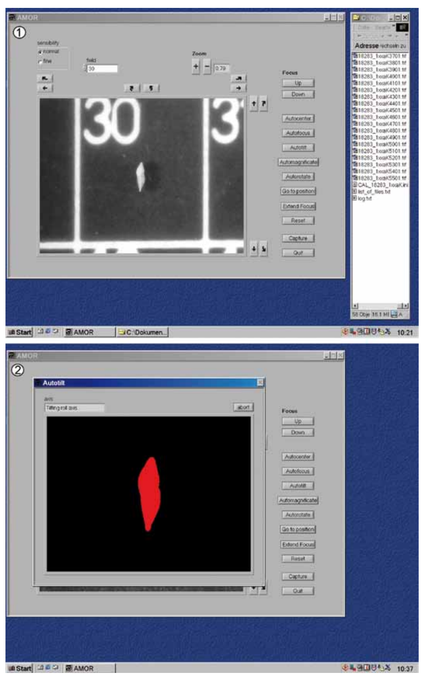


Zoom-motor for auto-mated magnification control.



AMOR with faunal slide inserted tilted to the right (“Roll”) and tilted forward (“Pitch”).

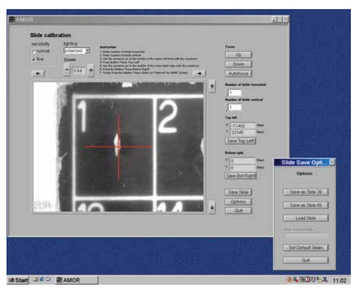
5. Basic functions



Autotilt:
In the „single measurement mode“ all mechanical movements can be activated by mouse-clicks: Centering a specimen to the active window, focusing, shifting left-right & up- and down, tilting (Pitch & Roll), searching for the optimum orientation), zooming, image rotation, and image capture.

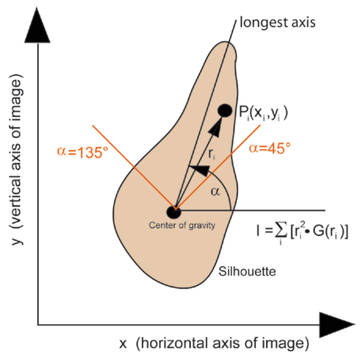
A LUT image is displayed during Autotilt, the operation which automatically orientates the specimen in keel or umbilical position. During Autotilt the red area is minimized during „Roll-movement“ (tilting left-right) and the longest axis is maximized during „Pitch“-movement (tilting forward-backward). After each tilting interval the specimen is automatically re-focused.

6. Special functions



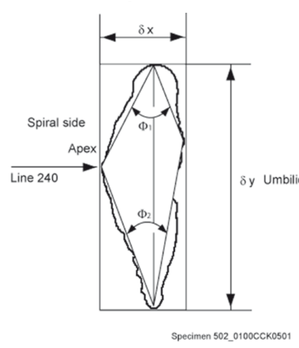
Slide calibration:
Because there exist different types of faunal slides the number of fields per slide can be manually specified.

In order to correct variations in slide dimensions (manufacturing errors), a slide calibration tool has been implemented. With this tool different types and brands of faunal slides can be used with AMOR.

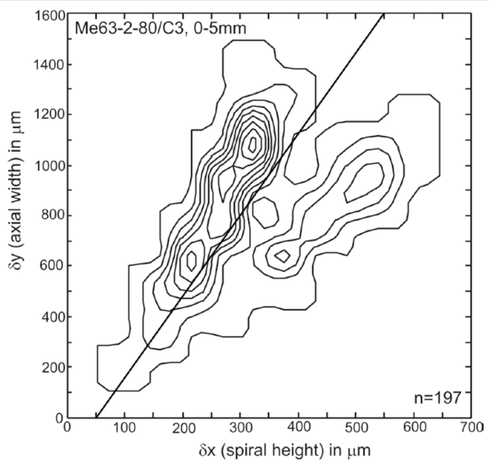


Autorotate:
This function rotates the imaged specimen on the monitor into a vertical position (longest axis of particle vertical). It calculates the momentum of inertia I of grey-levels of the specimen for every rotational position until I becomes a minimum. This is the case if the angle between the longest axis of the particle and the horizontal axis of the image is 90° (vertical) or 0° (horizontal). Because the elongate specimens are mounted in a pre-oriented orientation the horizontal case will never be reached.

7. Example results



Digitized shell of *G. menardii* in keel view, with morphometric parameters indicated. δx is the axial height of shell, δy is the diameter of shell in keel view.



Grid-cell: Δx=50µm, Δy=100µm
Contour intervals=2 specimens per grid-cell

Contoured frequencies from 197 Holocene *G. menardii* specimens in the bivariate morphospace of δx versus δy derived from images collected with AMOR. Such diagrams are useful to classify morphotypes. The line indicates a classification of morphotypes into forms similar to *G. menardii menardii* (below line) and into *G. menardii cultrata* (above line), see Knappertsbusch (2007).

8. Conclusions

The quantitative search of morphological speciation patterns and mapping of morphological trends through geography and time (“Evolutionary prospection”) requires large amounts of data, which can only be realized with automated tools.

The development of AMOR greatly facilitates the routine collection of digital images of positioned microfossils for, and it enhances precision.

Processing a faunal slide with 60 specimens requires about 2 hours.

Although development and refinement require considerable effort, routine application of AMOR outcompete any initial investment once calibration and quality control of data have been optimized.

9. Acknowledgements

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10. References cited

Knappertsbusch, M., Binggeli, D., Herzig, A., Schmutz, L., Stapfer, S., Widmer, L., Schneider, C., and Eisenecker, J. (in press). AMOR – A new system for automated imaging of microfossils for morphometric analyses. Palaeontologia Electronica, in press.

Knappertsbusch, M., (2007). Morphological variability of *Globorotalia menardii* (planktonic foraminiferan) in two DSDP cores from the Caribbean Sea and the Eastern Equatorial Pacific. Carnets de Géologie / Notebooks on Geology, Brest, Article 2007/04 (CG2007_A04).
URL: http://paleopolis.rediris.es/cg/CG2007_A04/index.html

Knappertsbusch (2004). MorphCol - A collection of Fortran 77 programs for geometric morphometry. Technical Report. Naturhistorisches Museum Basel, Augustinergasse 2, 4001-Basel, Switzerland, 120 pages.
URL: http://pages.unibas.ch/museum/microfossils/Research/MORPHCOL/Start.html