

AMOR2 follows AMOR - an improved robot for orientation and imaging of planktonic foraminifera

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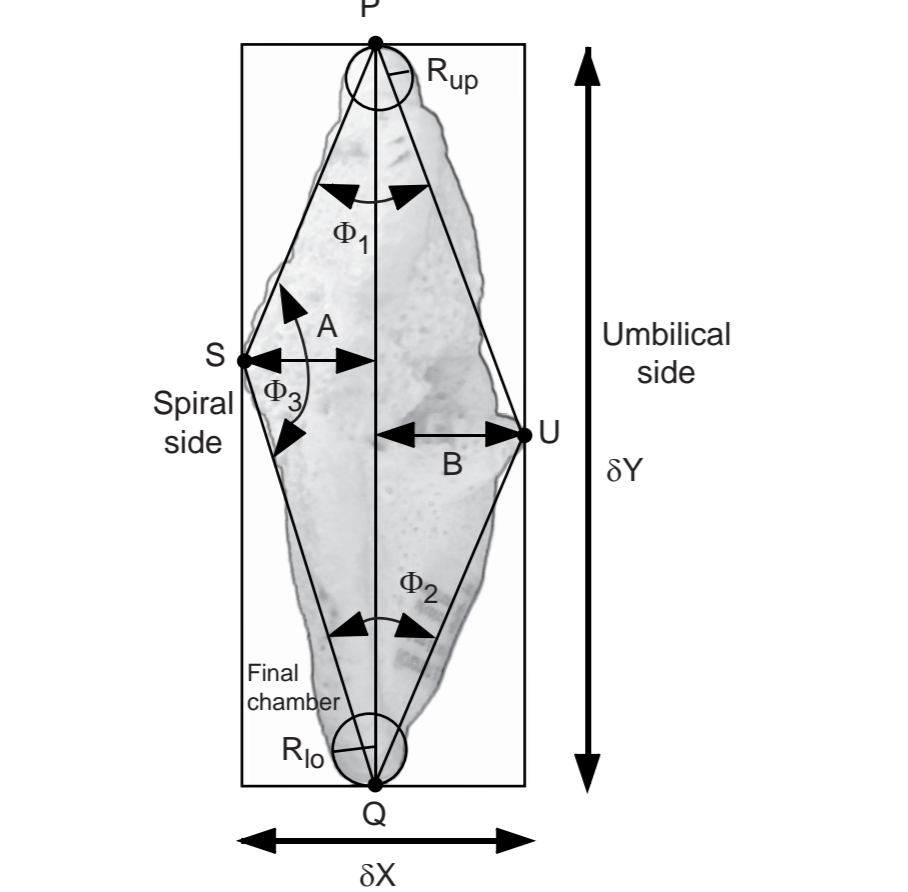
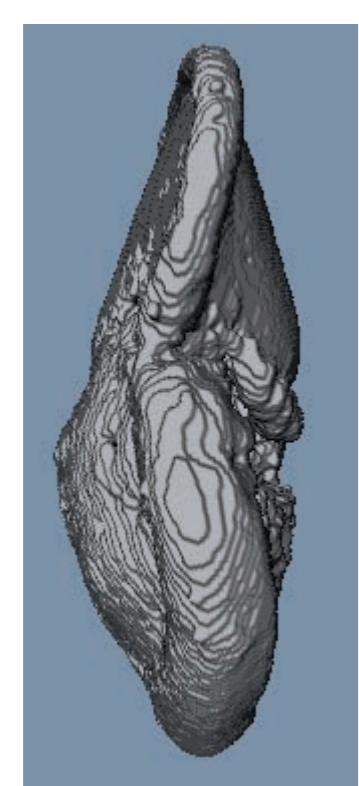
KEY WORDS: Automated imaging, morphometry, evolution, planktonic foraminifera

1. Abstract

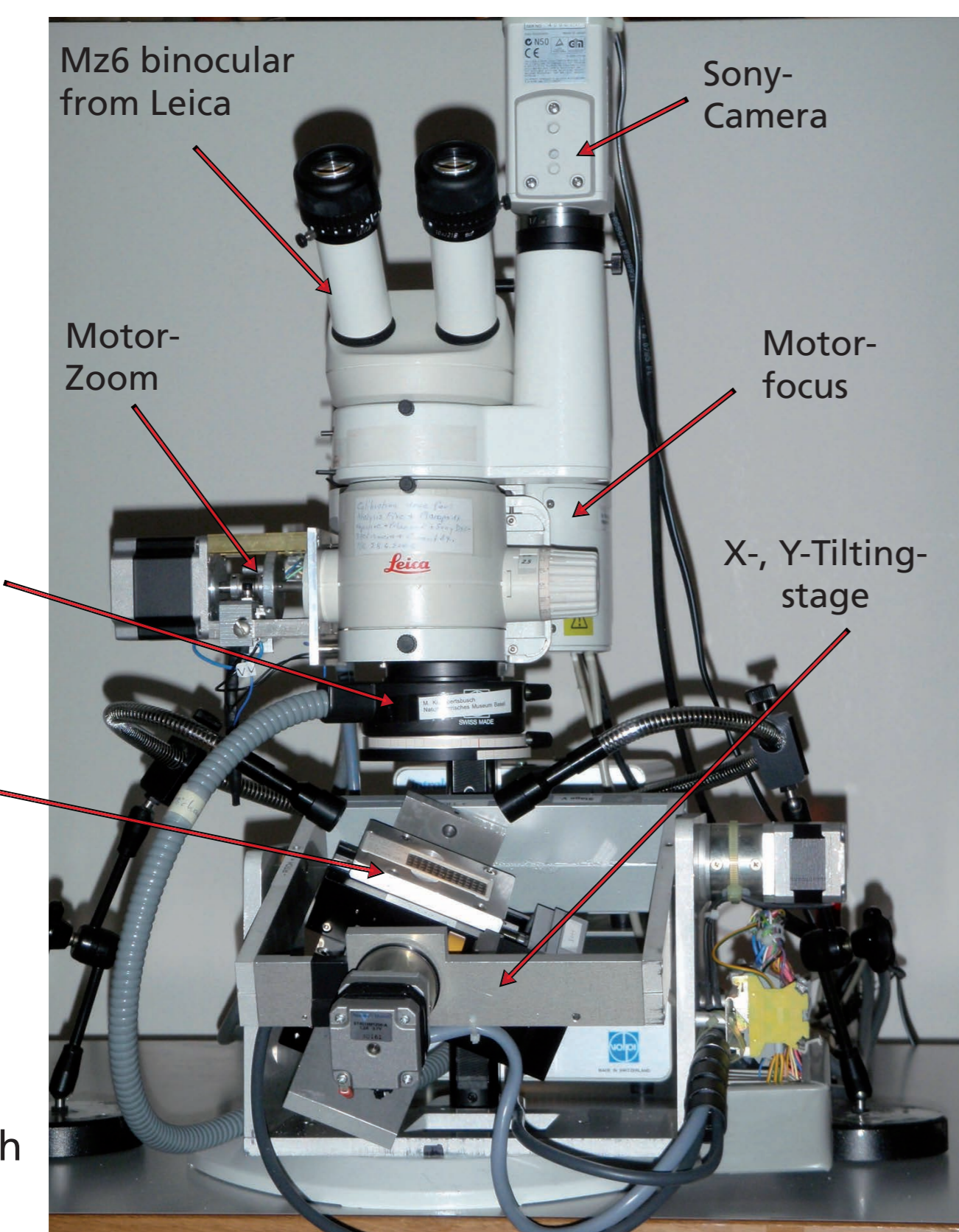
System AMOR2 is a robot for automated orientation and digital imaging of foraminiferal shells under a binocular microscope. AMOR2 was recently completed from its precursor - AMOR (**A**utomated **M**easurement system for shell **m**ORphology). The driving software is written in LabView from National Instruments. Core-functions include X- and Y tilting and translation, centering, autofocus, automagnification, autorotate of specimens and capture/saving images to disc. It has improved hardware (camera, motor-zoom, controller box), and extended functions allowing better orientation of asymmetric forms in keel view (spiro- and umbilico-convex profiles), or forms with circular periphery in aequatorial view. Both devices serve now for our ongoing prospection for shell evolution in menardiform globorotalids along the trackway of the Agulhas Current System.

2. Introduction - Rationale for AMOR: The case of *Globorotalia menardii* (planktonic foraminifera)

The evolution of menardiform globorotalids is quantified using shell parameters in keel view. Orientation into standard keel position is achieved with AMOR.



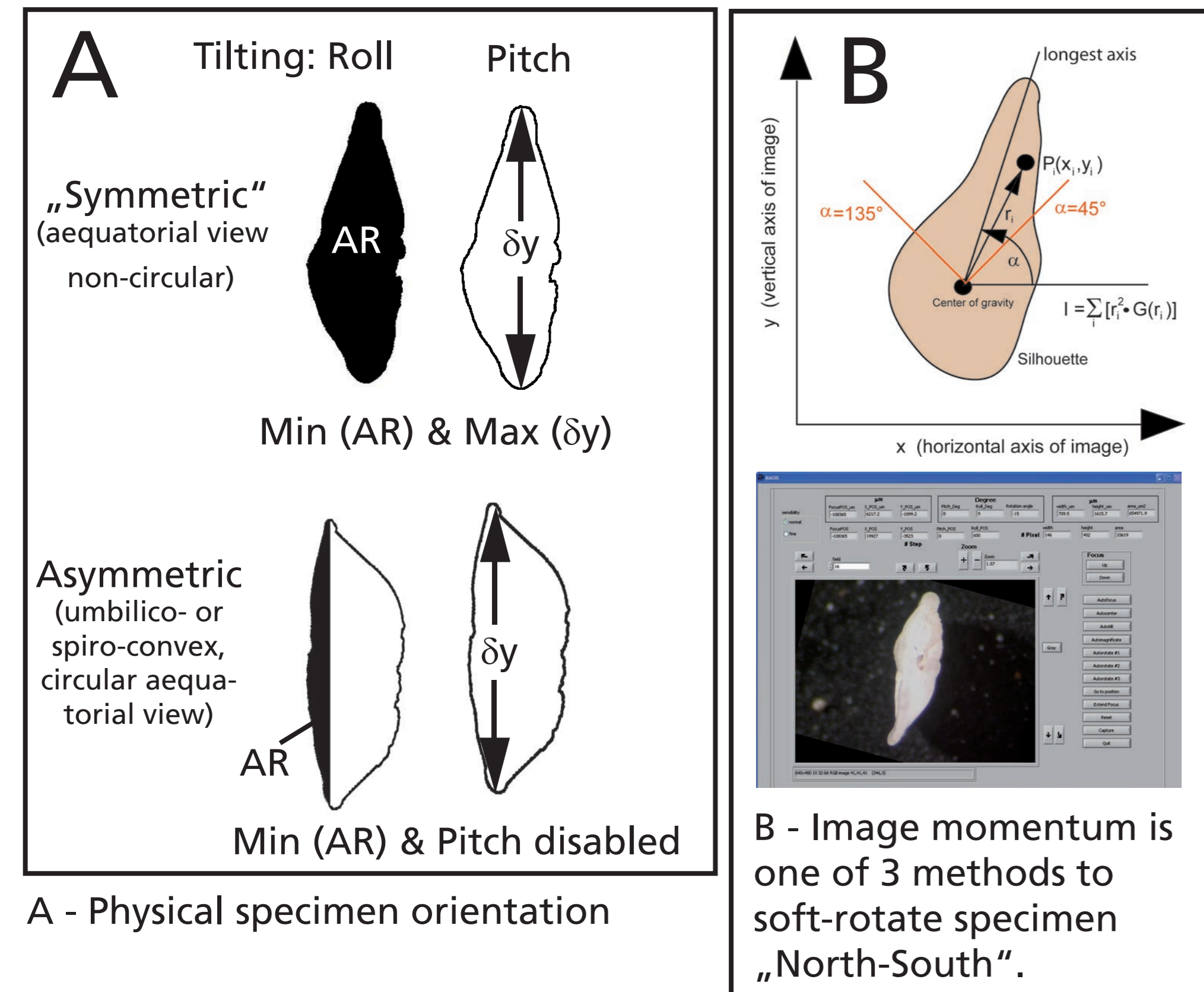
Works with standard Plummer-cells with 36 or 60 fields



Old AMOR (Knappertsbusch et al. 2009).

3. Principle of orientation in AMOR

Scheme for optimal shell-orientation in keel-view in AMOR:



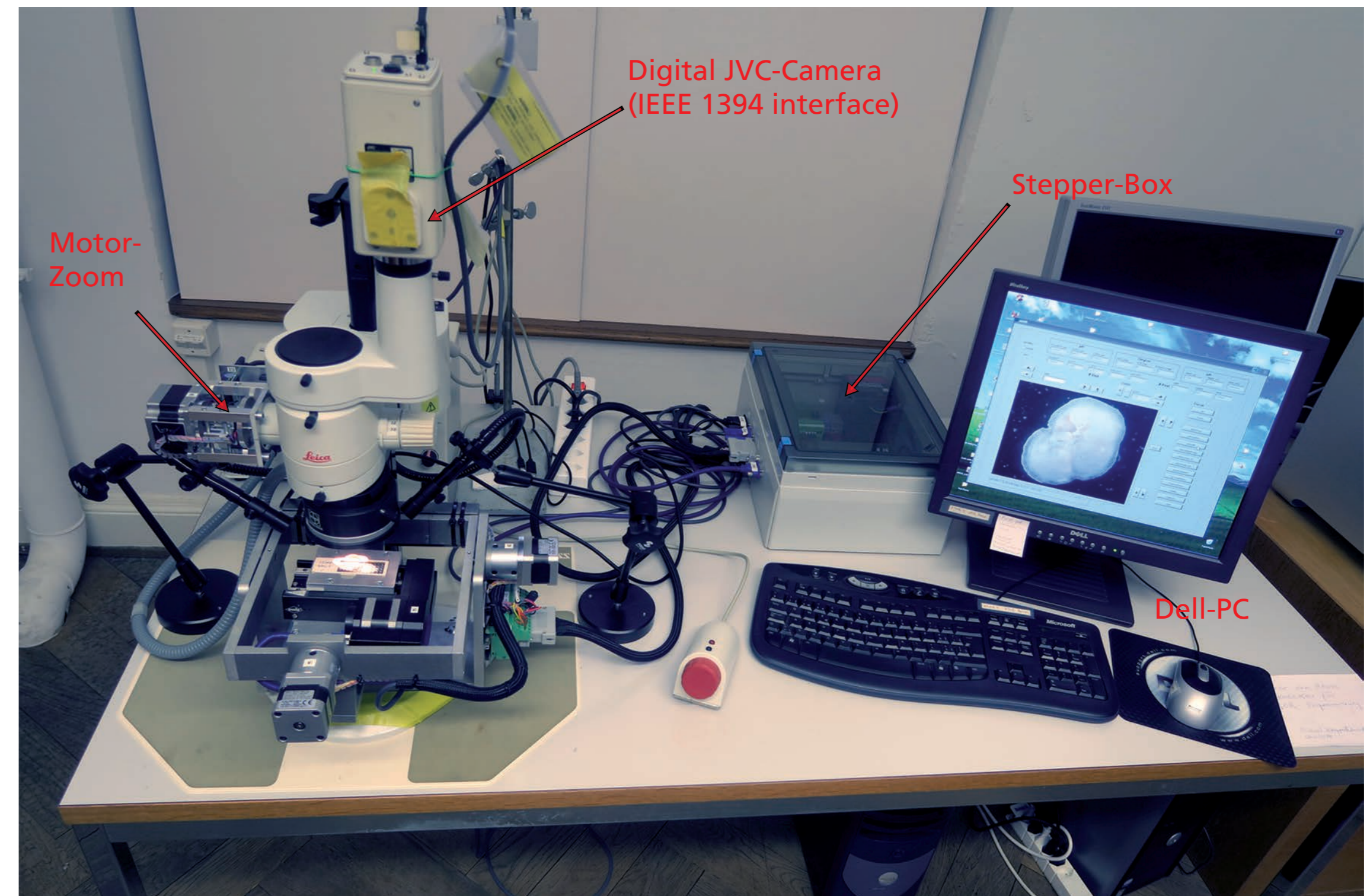
Implemented algorithm (simplified):

- 1.) Initialize, move to first specimen.
- 2.) Tilt specimen in X- (Roll) and Y (Pitch) direction while centering the specimen in the camera window and focus automatically.
- 3.) If best position (conditions above) is found zoom to highest possible magnification, Center, Focus.
- 4.) Soft-rotate Ferret diameter into „North-South“ on monitor.
- 5.) Save image and final magnification to disk.
- 6.) Check Stop criterion.
- 7.) Goto step 2 (i.e. move to next specimen).
- 8.) End.

4. The new System AMOR2 - Improvements



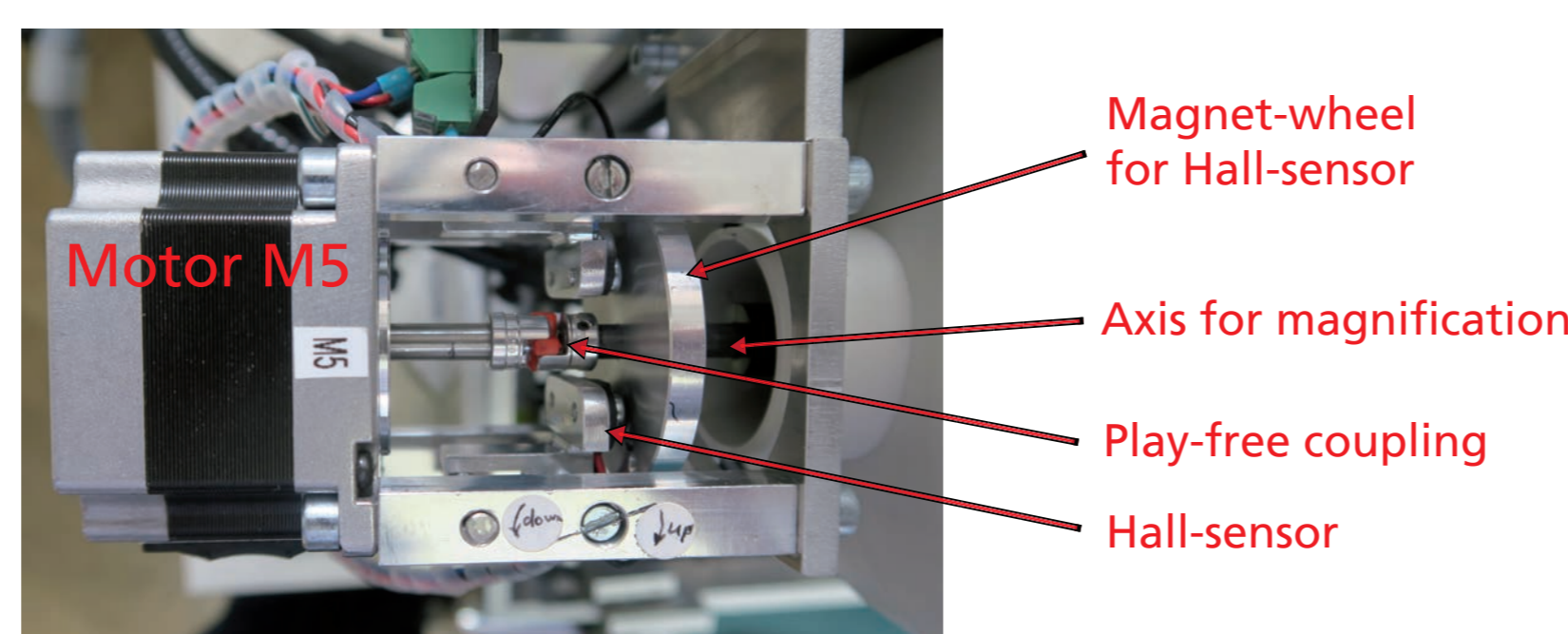
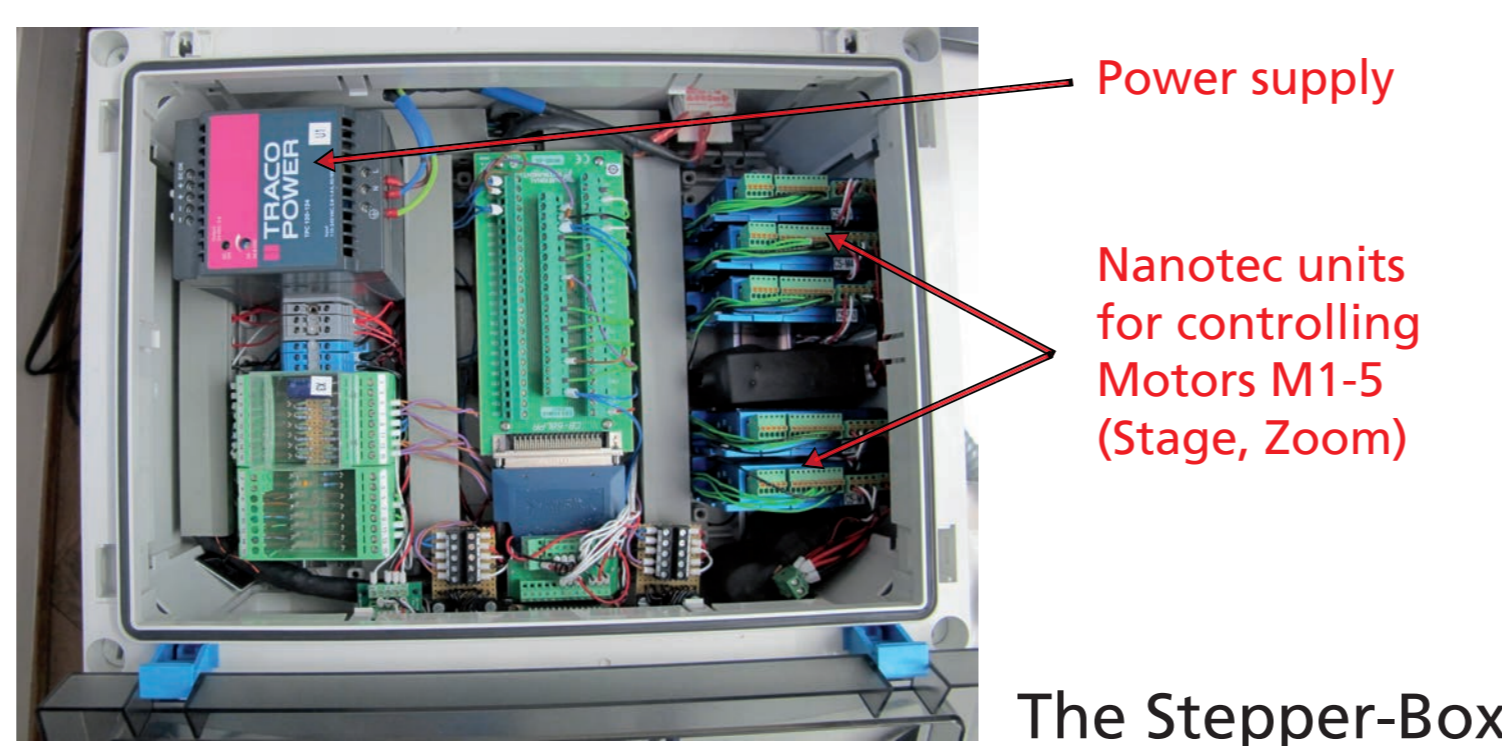
New system AMOR2, side view. Grey plug allows disconnecting Stepper-box from stage (was not possible before).



New system AMOR2, front view. New hardware includes digital JVC Camera (no extra framegrabber any more), a single Stepper-Box with motor controllers, power supply and electronics, and an improved motor-zoom with Hall-sensors as limit switches for zooming.

5. AMOR2 - New hard elements

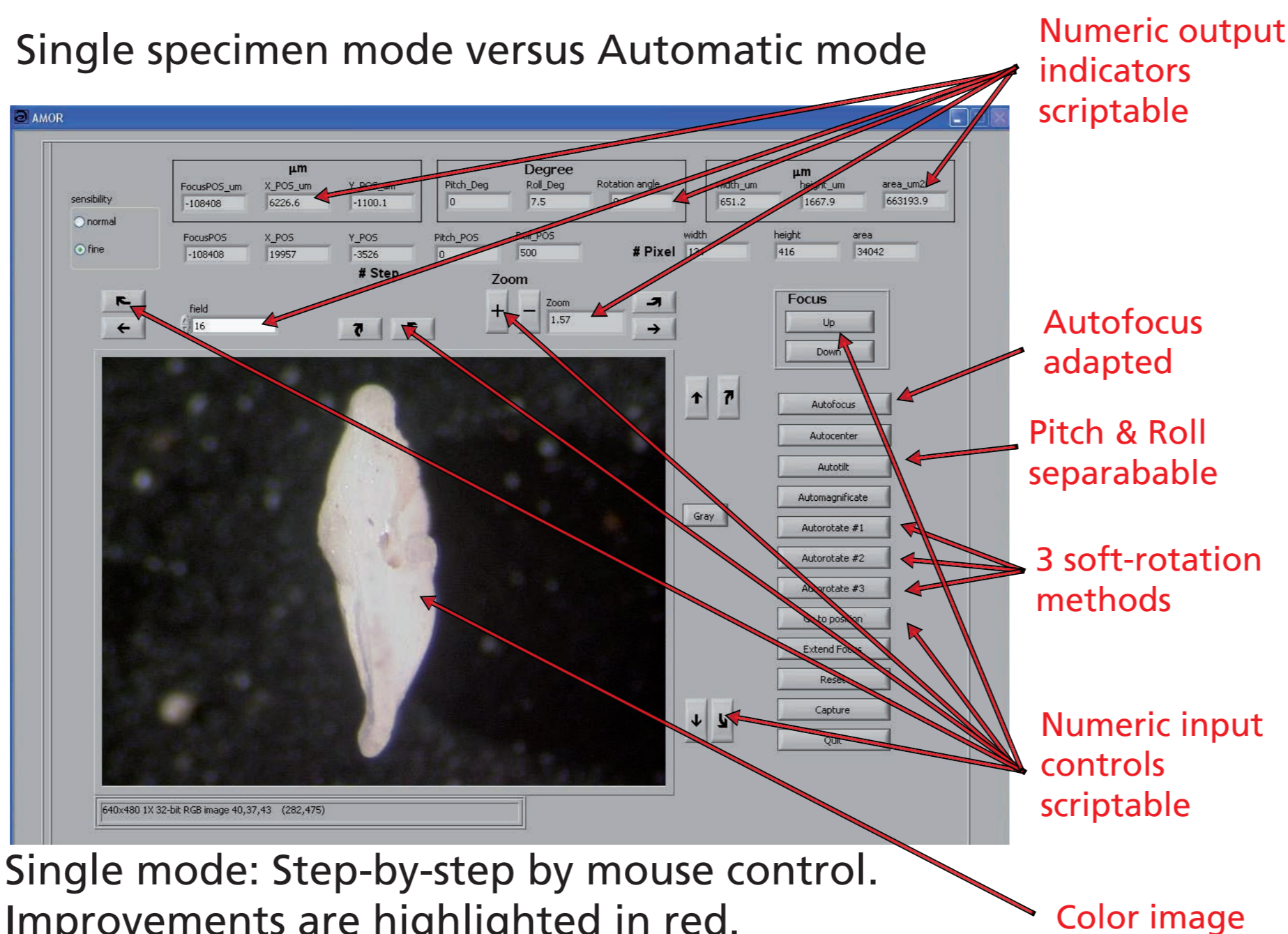
Central to AMOR2 is the new Stepper-Box, which combines the 5 controllers for stage motors (X and Y tilt and translation axes) and the zoom motor, limit switch electronics, power supply, and wirings. The new Stepper-box can now be disconnected from the Tilting-Stage for better transportation of the system.



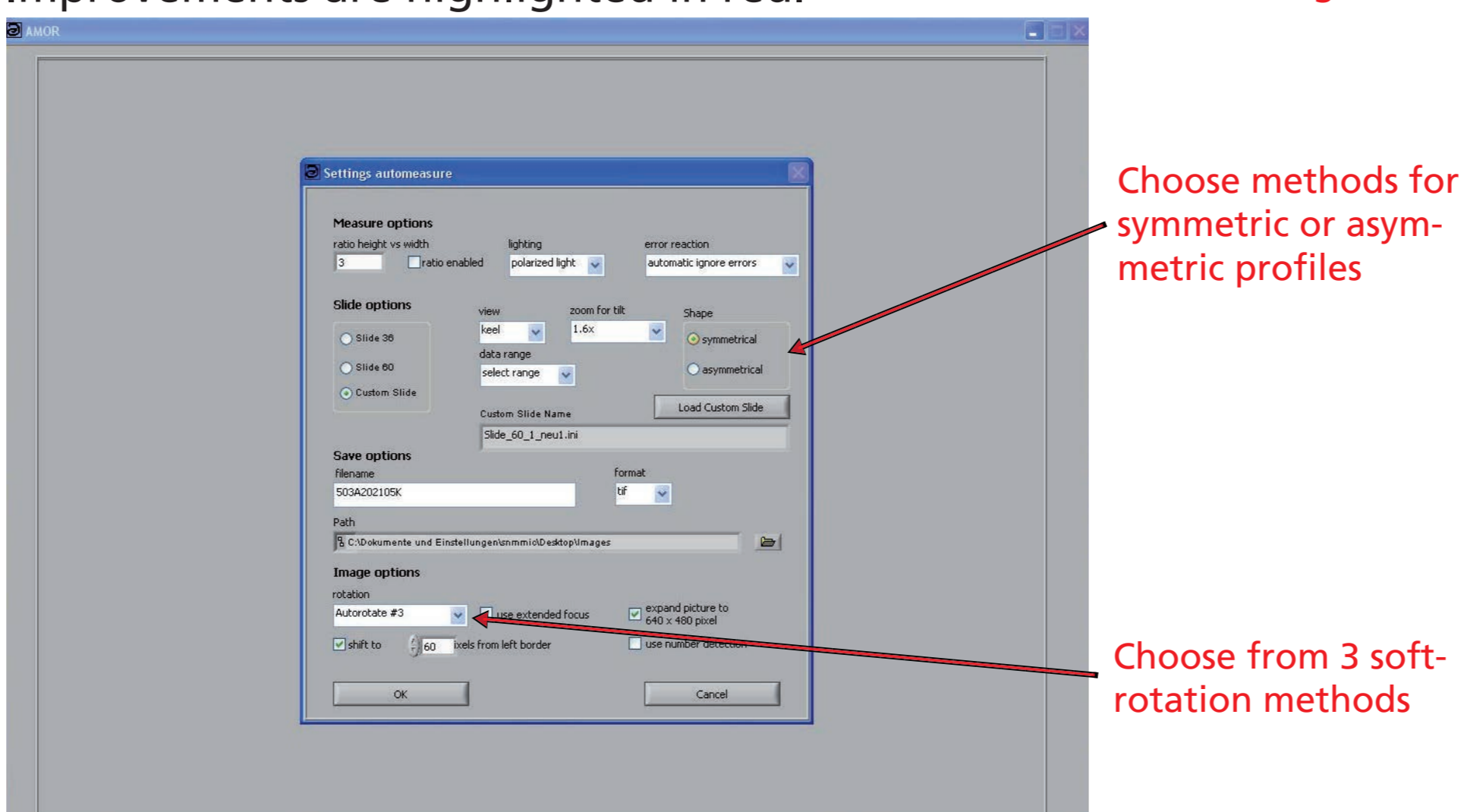
New motor-zoom with Hall-sensors instead of mechanical dip-switches for better detection of upper and lower limits of magnification.

6. AMOR2 - New soft elements

Upgrade - From previous Program AMOR v. 3.28 (LabView 8.5) to Program AMOR v. 4.2 (LabView 14) in new System AMOR2.



Single mode: Step-by-step by mouse control. Improvements are highlighted in red.



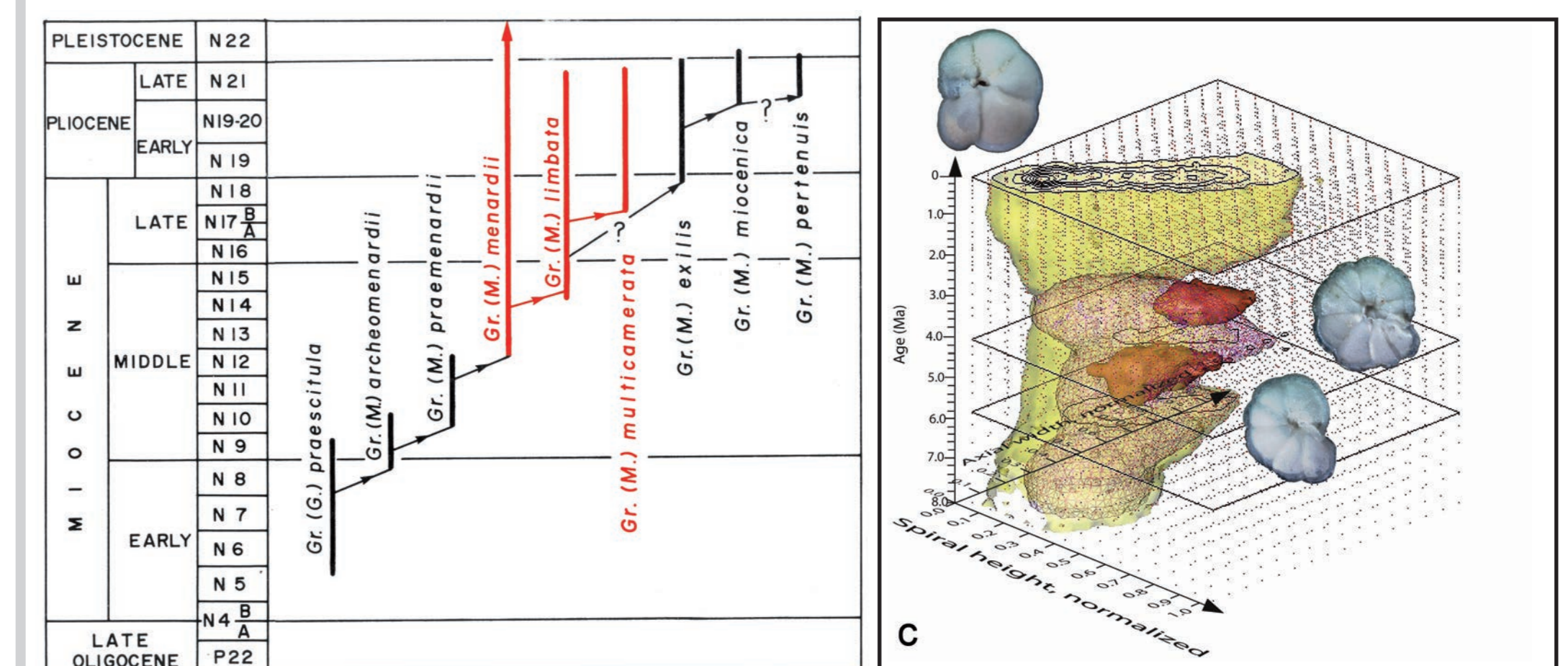
Automatic mode: Entire slide is batch-processed as a series of core-functions. New functions are highlighted in red.

7. Scripting AMOR

From AMOR v. 3.28 software onwards core-functions became scriptable through application of AutoIt scripting language from Jonathan Bennett and his team. It allows a case-dependent combination of core-functions, which increases flexibility without reprogramming sophisticated LabView code.

Implementation of numeric input controls / numeric output indicators enables creation of more complex „portfolio“ scripts for processing other morphologies than those from menardiform globorotalids.

8. Example - AMOR derived volume-density diagram illustrating morphological evolution in Neogene globorotalids



Left: Phylogeny of menardiform globorotalids after Kennett and Srinivasan (1983). Right: AMOR-derived volume-density diagram of spiral height (δX) versus axial length (δY) for the *G. menardii-limbata-multicamerata* lineage (highlighted in red in left figure) at ODP Site 925B for the past 8 Ma. *G. menardii* (yellow) is ancestral, from which intermediate *G. limbata* (pink) and terminal *G. multicamerata* (red) evolved (see Knappertsbusch, 2016).

9. Conclusions

The availability of robots for orientation and imaging of microfossils accelerates quantification of morphological evolution in foraminifera and so facilitates analysis of large specimen numbers at increased reliability and efficiency.

Evolutionary studies for foraminiferal shells from natural populations need species-specific algorithms in order to best orientate specimens into a standard positions for imaging.

Successful realisation of robotic tools requires continuous collaboration between taxonomists, micropaleontologists and engineers over a considerable period.

10. Acknowledgements

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11. References cited

Knappertsbusch, M. (2016). Evolutionary prospection in the Neogene planktic foraminifer *Globorotalia menardii* and related forms from ODP Hole 925B (Ceara Rise, western tropical Atlantic): evidence for gradual evolution superimposed by long distance dispersal? *Swiss J. Palaeontol.* 135:205-248. DOI 10.1007/s13358-016-0113-6

Mary, Y. (2013). Morphologic, biogeographic and ontogenetic of Mid-Pliocene menardellids (planktonic foraminifera). Dissertation Universität Basel. http://edoc.unibas.ch/diss/DissB_10611/

Knappertsbusch, M. & Mary, Y. (2012). Mining morphological evolution in microfossil diagrams. *Palaeontologia Electronica*, 15 (Issue 3; 7T): p. 29. <http://palaeo-electronica.org/content/issue-3-2012-technical-articles/282-volume-density-diagrams>

Knappertsbusch, M., Binggeli, D., Herzig, A., Schmutz, L., Stapfer, S., Schneider, C., Eisenecker, J. and Widmer, L. (2009). AMOR-A new system for automated imaging of microfossils for morphometric analyses. *Palaeontologia Electronica*, 12 (Issue 2, 2T): p. 20. http://palaeo-electronica.org/2009_2/165/index.html

Kennett, J.P. and Srinivasan, M.S. (1983). Neogene planktonic foraminifera. A phylogenetic atlas. Hutchinson Ross Publishing Company, Stroudsburg, Pennsylvania, 265 p.

See also <https://www.micropal-basel.unibas.ch/Research/AMOR/AMOR.html>