FAST SYNCHROTRON X-RAY MICROTOMOGRAPHY OF EXTANT AND FOSSIL INSECTS

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Summary: By employing fast synchrotron X-ray microtomography, we analyzed various extant and fossil insects. Our results demonstrate the importance of the technique for different research areas like functional morphology, paleontology and biomimetic design. Further, we highlight the value of semi-automated image segmentation for the fast and accurate analysis of tomographic data.

1. INTRODUCTION

In recent years, synchrotron-based X-ray imaging became an established method for the examination of small animals and X-ray microtomography in particular is an important tool for the non-destructive 3D imaging of insects and other arthropods. The talk features recent results of fast X-ray imaging experiments on insects, which were performed in the scope of the projects ASTOR and NOVA, including examples from various research field like functional morphology, paleontology and biomimetic design. Emphasis is also given to the (semi-)automated analysis of complex tomography data.

2. EXPERIMENTAL METHOD

All experiments were performed at the fast imaging stations of KIT's Institute for Photon Science and Synchrotron Radiation (IPS). The measurements consisted of the acquisition of 2,500 - 3,000 equiangularly spaced radiographic projections of the sample in a range of 180°. A parallel polychromatic X-ray beam was detected by an indirect X-ray area detector, coupled to a pco.dimax camera with a pixel matrix of 2008x2008 pixels. The magnification of the optical system was adjusted to the sample sizes, usually yielding an effective X-ray pixel size of 3.66 µm or 1.22 µm. Tomographic reconstruction was performed with the GPU-accelerated filtered back projection algorithm implemented in the software framework UFO [1] Data was post-processed and analyzed using the ASTOR virtual analysis infrastructure (http://astor.kit.edu/). For the semi-automated image segmentation we employed the "Biomedical Image Segmentation App" (Biomedisa) developed by one of the authors (P.L.).

3. RESULTS

The experiments demonstrated the value of fast X-ray for the digitization and 3D analysis for minute biological samples. We were able to scan thousands of different specimens and while the analysis is still on-going, it already lead to several interesting discoveries. Interactive 3D models based on tomography data allowed analyzing complex motion systems in arthropods [2]. The elytra of beetles proved to be interesting role models for biomimetic design and lead to the construction of a research pavilion [3]. When studying 30-million-year old mineralized beetles from the fissure fillings of the Quercy region in France, we found that also insects from non-amber collections may contain detailed internal anatomical characters, thus allowing species description and phylogenetic analysis as done for extant specimens [4]. These findings suggest that mineralized insects constitute

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a comprehensive, but yet largely neglected source for three-dimensional anatomical data. Moreover, the semi-automated segmentation employed here turned out to be much faster and more accurate than manual segmentation and proved to be invaluable when dealing with a huge amount of specimens.

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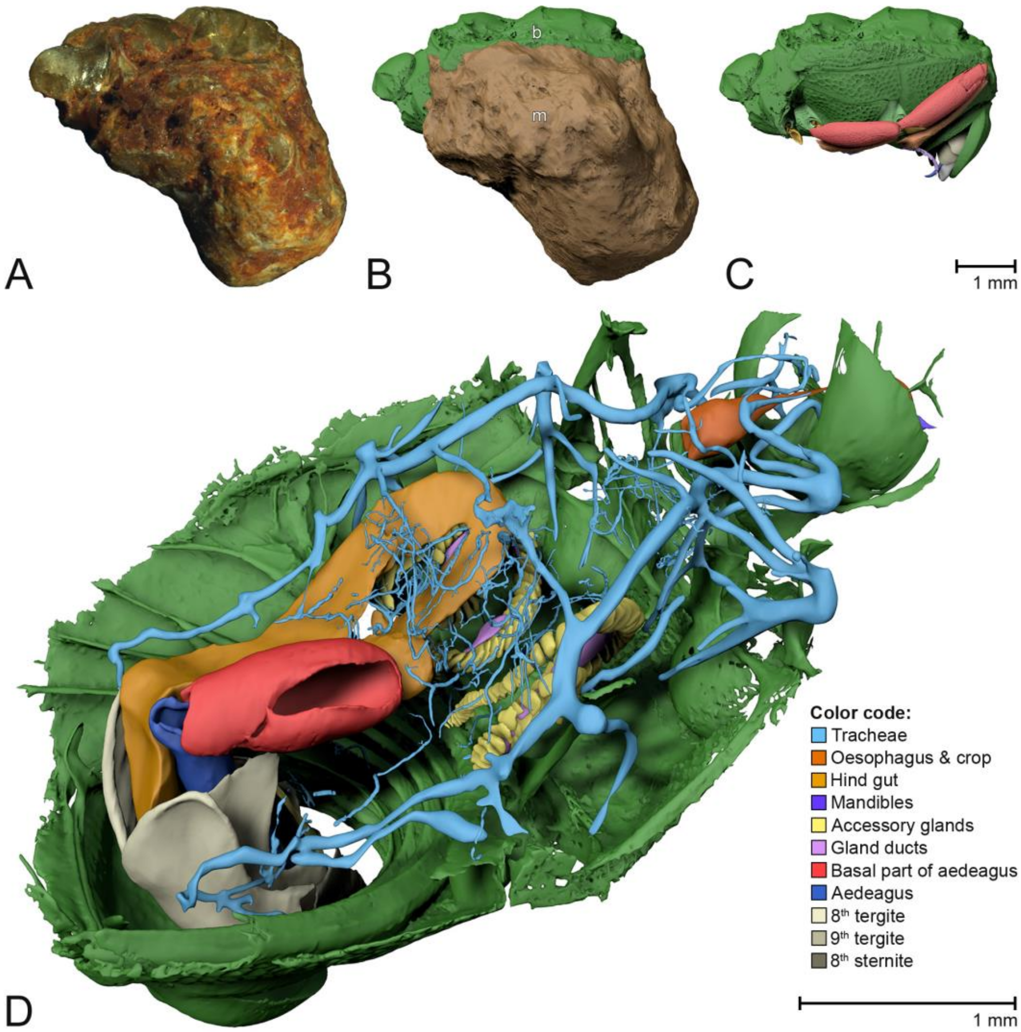

(b)

Figure 1: Digital reconstruction of a fossil histerid beetle [5]. **A** Photograph of the fossil ventrally embedded in a stony matrix. **B** Digital reconstruction showing fossilized beetle (b) and matrix (m). **C** Beetle digitally isolated from the stone, revealing well-preserved morphology hidden by the matrix. **D** Perspective view of the fossil showing parts of exoskeleton, tracheal network, alimentary canal and genitals.