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3D reconstruction of BigBrain2: Challenges, methods and status of histological section repair –A progress report

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Reconstruction of a BigBrain dataset from serial histological sections is highly labour and time intensive and requires a significant technical effort. To obtain a high-quality 3D reconstruction from accurate image registration, it is necessary to correct images from artifacts that can arise from cutting and from further histological processing steps (e.g., cracks, ripples, holes), even if all processing steps are performed with great care and expertise. Previous work on such a dataset showed that the effort for repair is the most critical factor in the total time required to reconstruct the dataset. Strategies for these repairs are presented, discussed, and classified in terms of their effectiveness, amount of required manual work and computational requirements. An overview of typical damages seen in histological sections is provided with an estimate of their relative frequency. Due to the number and variety of these damages, fully automatic procedures quickly prove to be insufficient. To enable time-effective repair of thousands of sections, optimized, and easy-to-use frameworks as well as quality control (QC) and consistent provenance tracking tools are essential. Methods that have already been applied in practice are presented.

We developed a semi-automatic procedure considering different approaches depending on the overall quality of individual sections. E.g., if the damage is present in an individual section, information from adjacent sections can be used for an automatic repair, which is not feasible if the damage affects several consecutive sections. Further, damages should not be repaired if they were already present after removal of the brain, because such damages are also imaged in the MR dataset, used hereby as an undistorted shape reference in the reconstruction, and their elimination could mislead the registration. Our processing pipeline is based on a recursive multi-resolution approach with integrated provenance tracking, initially generating a coarse-resolution reconstruction that is increased in iterative steps to the final resolution of 0.02x0.02x0.02 mm.

Based on this general framework, we will report on the progress in the repair of the so-called BigBrain2, which consists of 7676 histological sections. Every 5th section was fully repaired manually. Subsequently, a semi-automatic repair framework was applied to the intermediate sections. Each original, unrepaired image was first nonlinearly transformed to the immediately adjacent repaired sections. Using the computed transformation, the repaired image was then transformed into the space of the adjacent unrepaired sections and used to assist the automatic repair of the section. In contrast to our previous approaches, the protocolled repair information is additionally used to improve the repair of damages affecting several adjacent sections. To evaluate the results, an easy-to-use online tool for quick visual control of the sections in the different processing stages has been developed. In cases QC indicates that the result does not meet the required quality standards, the section is returned into the pipeline for another iteration.

Our intermediate results show that the improved approach for semi-automatic repairs with provenance tracking and online QC accelerates the very time-critical repair process within the overall 3D BigBrain dataset reconstruction.

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