Automatic workflow for the analysis of large batches of micro-tomographic scans of human teeth

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Abstract

The abstract will be written at the end, here are some key points

- Python
- Only free and open-source software
- Image analysis
- Fully reproducible research
- Efficiently done, already during scan of parts of the batch. New scans are just dumped on the script to process.
- Probably not possible manually in the needed time-frame or extremely cumbersome (huge batch-process).
- Everyone can do/check it, show it in Binder!

Introduction

Hereby we present a method to efficiently and reproducibly analyze large batches of teeth.

Materials & Methods

Teeth

Describe how the teeth have been collected and stored.

X-ray microtomography

After preparation of the teeth, the 104 samples were imaged on a Bruker SkyScan 1272 high-resolution microtomography machine (Control software version 1.1.19, Bruker microCT, Kontich, Belgium). To facilitate the scanning of this large batch of samples, we used the automatic sample changer to enable us to scan batches of 16 teeth without manual intervention. In addition to the sample changer, the machine is equipped with a Hamamatsu L11871_20 X-ray source and a XIMEA xiRAY16 camera.

We used a custom-made sample-holder to scan the teeth on the sample changer. The sample holder has been 3d printed and is freely available online (https://git.io/JJbAZ) as part of a library of sample holders [1].

The X-ray source was set to a tube voltage of 80.0 kV and a tube current of 125.0 µA, the x-ray spectrum was filtered by 1mm of Aluminium prior to incidence onto the sample. For each sample, we recorded a set of either 4 or 5 stacked scans overlapping the sample height, each stack was recorded with 482 projections of 1632 x 1092 pixels at every 0.4° over a 180° sample rotation. Every single projection was exposed for 950 ms, 3 projections were averaged to one to greatly reduce image noise. This resulted in a scan time of approximately 40 minutes per stack and between 2 hours and 40 minutes to 3 hours and 15 minutes per sample. In total, we thus scanned for approximately 13 days. The projection images were then subsequently reconstructed into a 3D stack of axial images spanning the whole length of each tooth with NRecon (Version 1.7.4.6, Bruker microCT, Kontich Belgium) using a ring artifact correction of 14. The whole process resulted in datasets with an isometric voxel size of 10.0 µm.

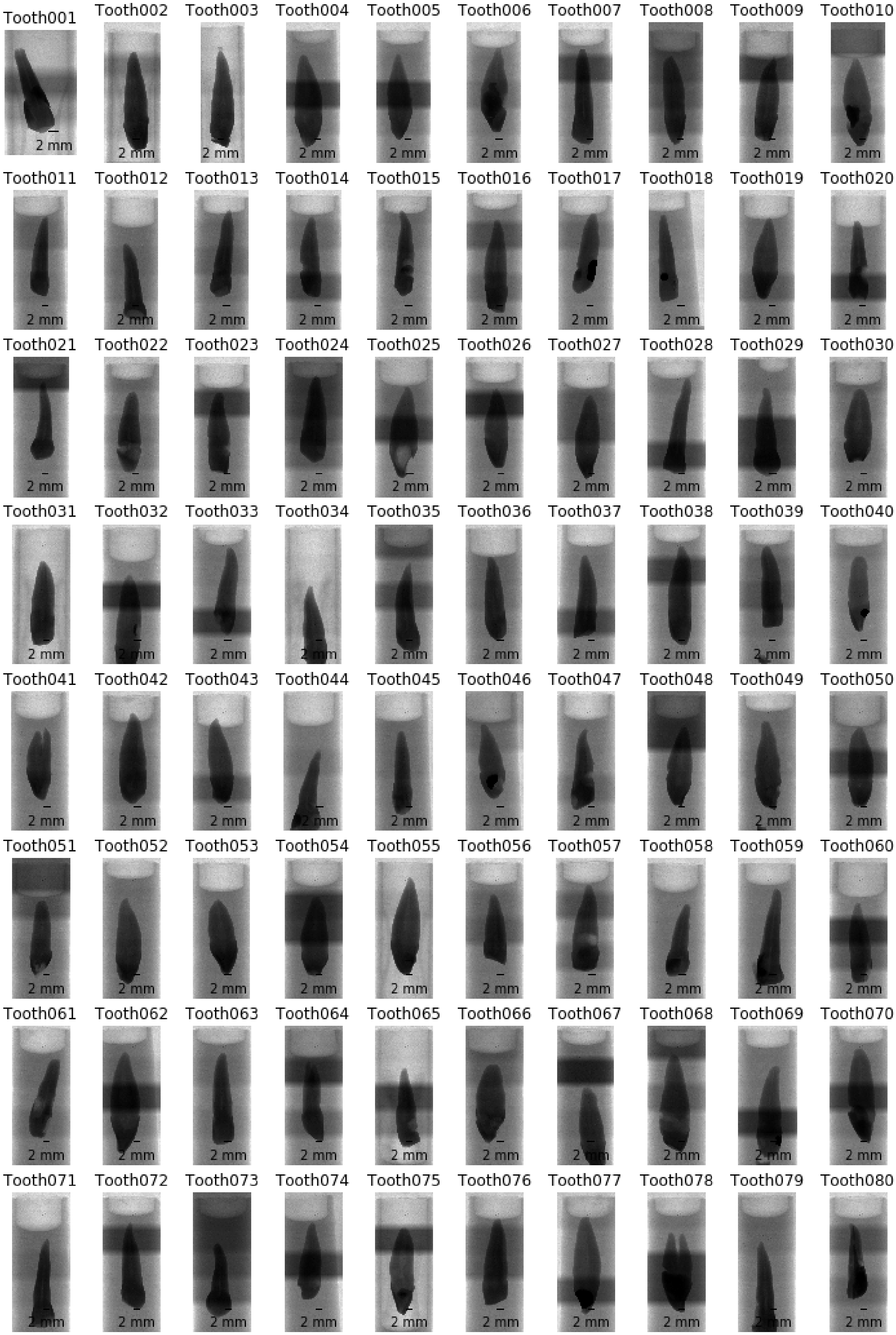
We recorded on average 8.17 GB of raw data for each tooth, totalling to 849.59 GB for all the 104 teeth.

Image analysis

Already during scanning the first items of the batch, we wrote a Jupyter [**???**] notebook with Python code which permitted to check the already performed scans as soon as they were reconstructed. Reruns of the notebook added newly scanned and reconstructed teeth to the analysis, facilitating preliminary checks and analysis of already scanned teeth. The notebook we used for the analysis presented in this manuscript is freely available online [2]. The important steps of the analysis steps are described in detail below.

Preparation

In a first step we extract all wanted parameters from the log file of each scan to store into a Pandas [3] dataframe for comparing and double-checking all the necessary scan parameters of each tooth scan with all the others. Afterwards, we loaded the preview image of each scan and then generated an overview image of all the scans (see Figure 1).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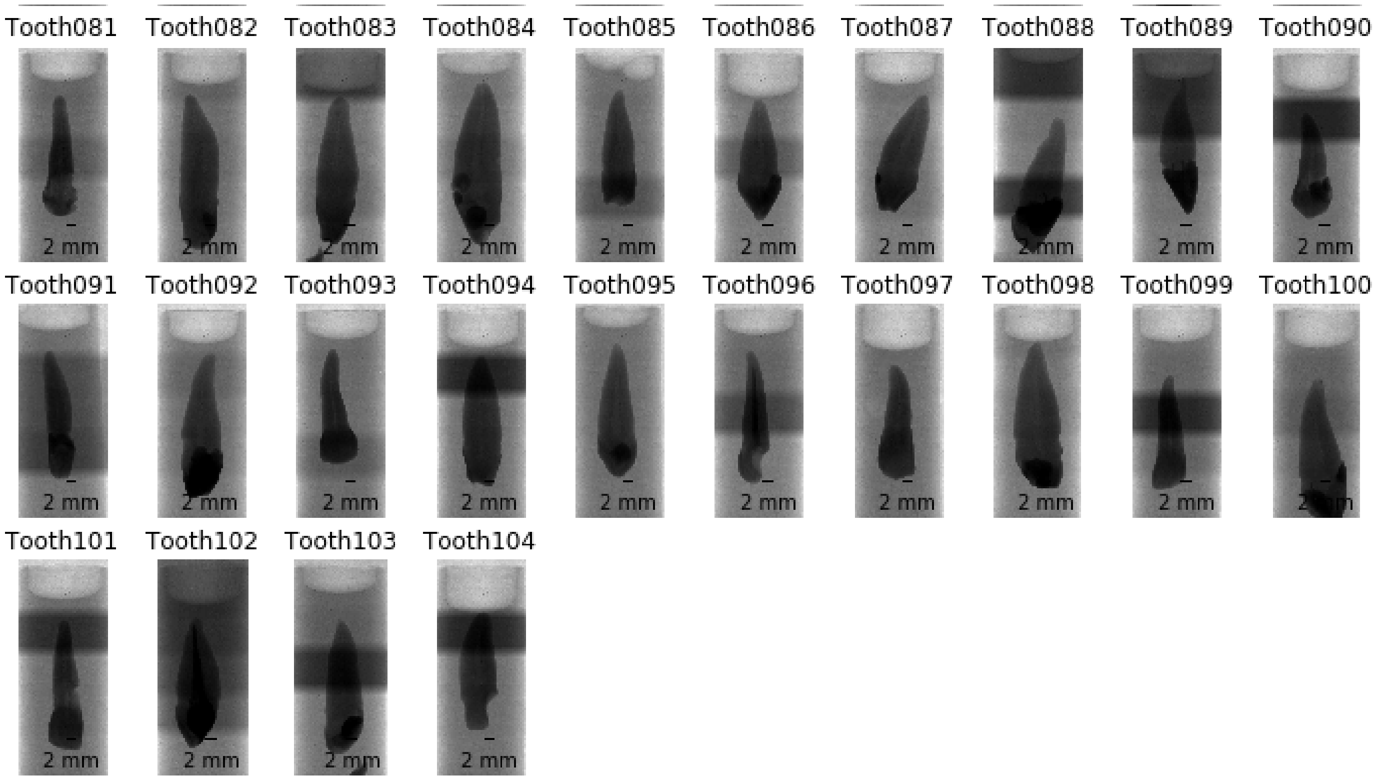

Figure 1: Overview images for each of all the teeth we scanned. It is immediately visible that several teeth slipped down in the holder. Since we were particularly interested in the bottom part of the teeth this poses no problem for further analysis. The irregular illumination stems from the rudimentary stitching process and is not visible in the reconstructed slices.

And here's some more text.

References

[1] D. Haberthür, TomoGraphics/Hol3Drs: A release, Zenodo, 2019. https://doi.org/10.5281/zenodo.2587555.

[2] D. Haberthür, habi/zmk-tooth-cohort: Used for manuscript about method, Zenodo, 2020. https://doi.org/10.5281/zenodo.3999402.

[3] W. McKinney, Data Structures for Statistical Computing in Python, SciPy. (2010). https://doi.org/10.25080/majora-92bf1922-00a.