Fast, Robust and Efficient Extraction of Book Pages from a 3-D X-ray CT Volume

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Introduction

Historical Document Analysis

For many historical documents, the standard procedure of using a book scanner is not applicable, because the document would get damaged by the page-turning process.
For writing, historical iron gall ink is used since the 5th century until present [1]. This kind of ink consists of metallic particles.

Non-Destructive Testing (NDT)

State-of-the-art NDT approaches:

- Terahertz [2]
  ➡ *Low depth resolution*
- X-ray phase contrast [3]
  ➡ *Expensive and immobile*

➢ X-ray CT scanners (micro-CT) [4]

Challenges

Fig.1. shows that a single page can not be easily investigated due to wavy pages and squeezing.

➢ Need of an algorithm for extraction and 2-D mapping of pages

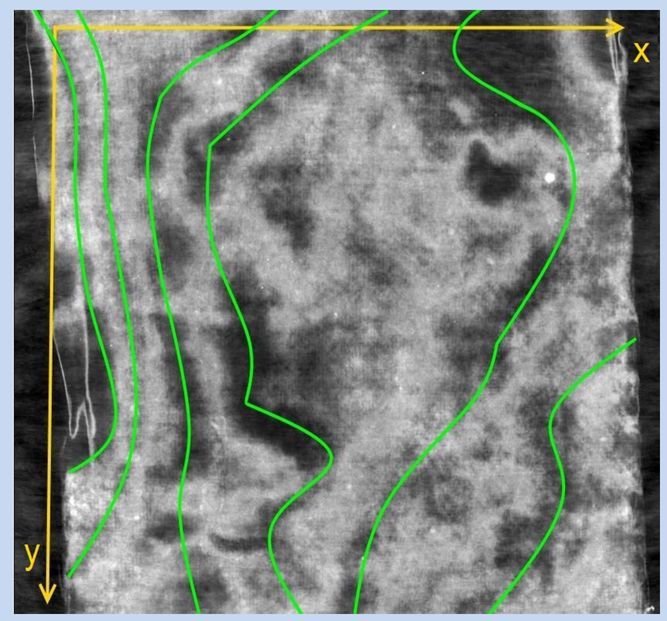

Fig.1. Volume slice of micro-CT scan. Green lines denote page's air gaps.

Materials and Methods

Book Model

- Handmade paper, thickness $200\ \mu m$, ten pages
- Iron gall ink writings
- Pressboard holder

3-D Scan and Reconstruction

- Cone beam geometry, book upright
- $360°$ scan with 2400 projections
- $70\ kVp$ and pixel shift $80.7\ \mu$m
- FDK reconstruction, 68 μm^3 voxels

Page Extraction Algorithm

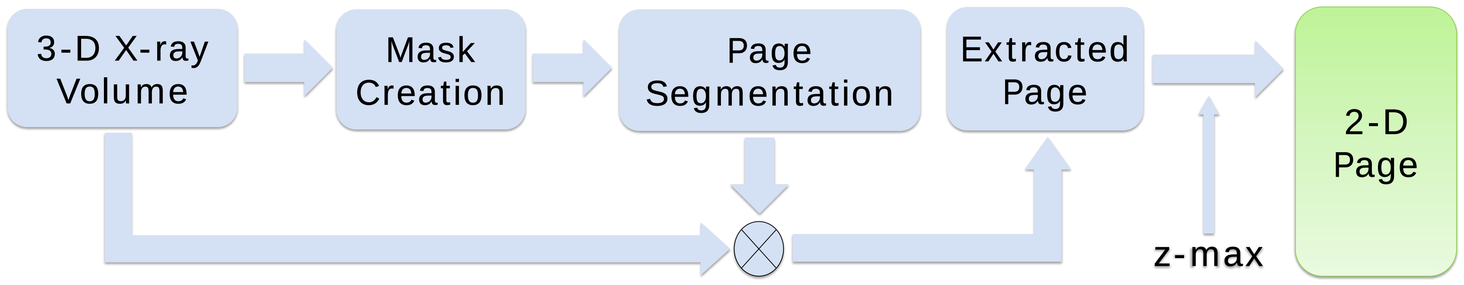

Fig.2. 3-D Volume Processing Pipeline demonstrating the process of the 2-D page mapping

Mask Creation:
Median filtering and Adaptive Gaussian Thresholding of yz-layer

Page Segmentation:
The user selects two points p_1, p_2 (Fig.3). For both points the pages $I_{p_{1,2}}$ are extracted separately. The segmentation result is calculated by evaluating the three occurring scenarios and finally z-max filtered.

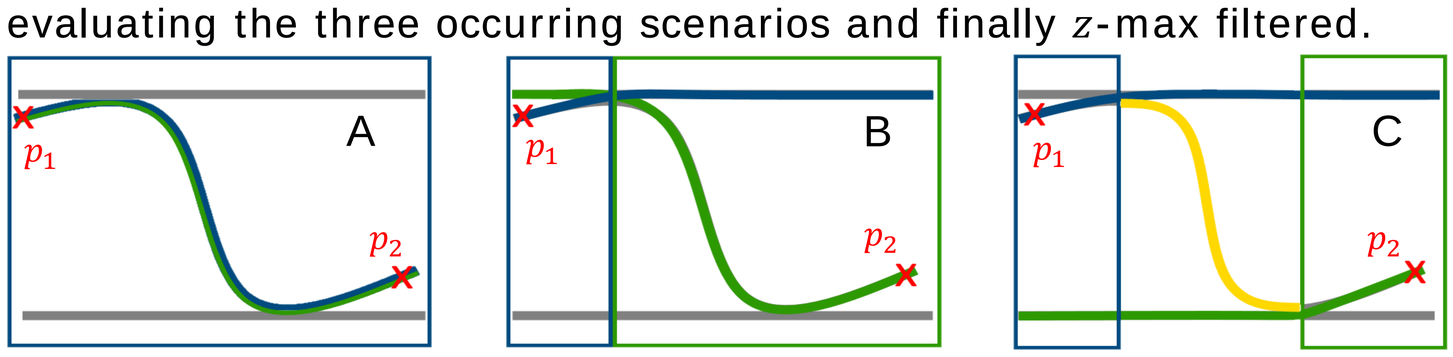

Fig.3. Possible segmentation scenarios with start points p_1, p_2 (red), I_{p_1} denoted blue and I_{p_2} denoted green: (A) Correct segmentation – Solution: I_{p1}. (B) Semi-correct segmentation - Solution: Left part of I_{p_1} and right part of I_{p_2}. (C) False Segmentation – Solution: Segmentation $I_{p_{1,2}}$ with smallest distance d to previously stored centerline. If the distance is greater than a certain threshold, the old centerline (yellow) is set as solution in this area.

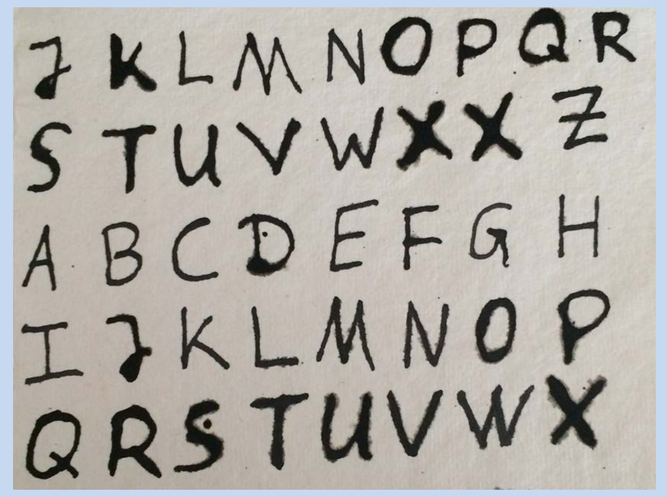

Fig.4. Original page of the book model

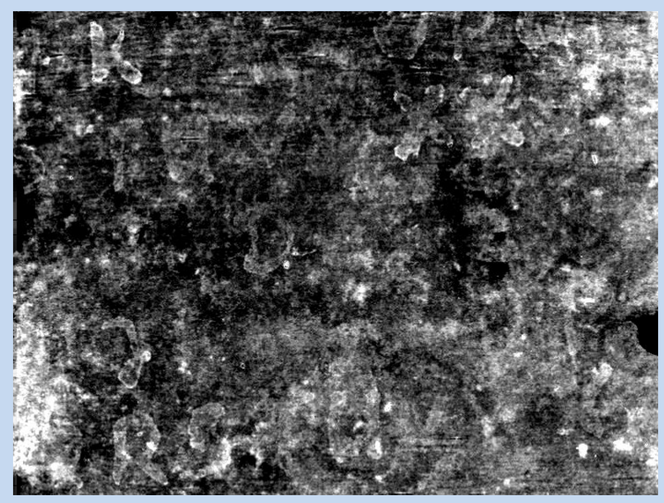

Fig.5. Extracted and 2-D mapped page

Results and Discussion

- Test image: Fig. 3 shows that the page is extracted properly, even when it is wavy, thin and has multiple overlaps. Application on real data shows similar results.
- Fig. 5 shows the extracted and 2-D mapped original page shown in Fig. 4.
- Missing letters are caused by the relatively high radiation energy of 70 kVp (not in scope of this work)
- Pressboard holder caused artifacts and new measurements without show highly improved results

Conclusions and Outlook

- Algorithm extracts and 2-D maps a page-of-interest
- Only little user interaction needed and easily adaptable
- Low computational time (~3 minutes with standard GPU)
- Future work: Improve scan, fully-automatic extraction, iterative reconstruction approaches, real historical documents

References

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[4] D. Stromer, V. Christlein, G. Anton, P. Kugler, and A. Maier, "3-D Reconstruction of Historical Documents using an X-Ray C-Arm CT System," in Proceedings of the 31th IVCNZ 2016, Massey University, 2016.