Project Management and Software Development for Medical Applications

Image Processing for Digital Breast Tomosynthesis

Final Presentation, 25.07.2023
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Section 01

Background & Motivation

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Digital Breast Tomosynthesis

- 3D images reconstructed from 2D X-ray projections
- Cross-sectional visualization via slices

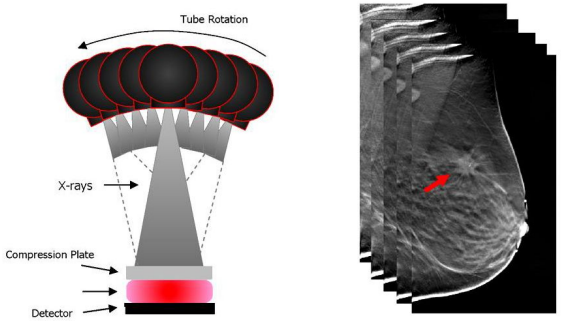

Figure 1. Acquisition Geometry of Digital Breast Tomosynthesis [1]

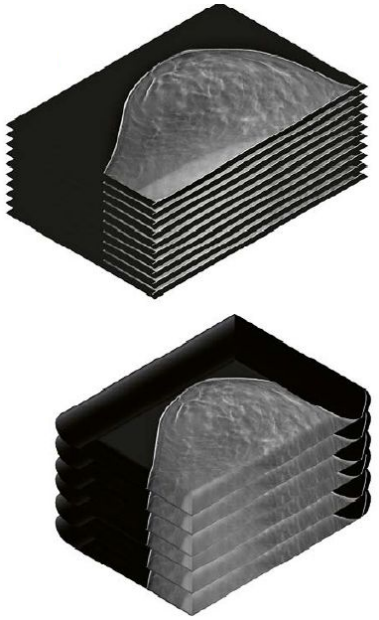

Figure 2. Slabbing slices [2]

[1] D. Kontos, P. R. Bakic, and A. D. A. Maidment, "Texture in digital breast tomosynthesis: a comparison between mammographic and n tomographic characterization of parenchymal properties," in Proc. SPIE, vol. 6915, Mar. 17, 2008, p. 69150A. doi: 10.1117/12.773144.
[2] HealthManagement.org, “Digital Breast Tomosynthesis in screening – approaches to reduce reading time,” HealthManagement, https://healthmanagement.org/c/decision-support/whitepaper/digital-breast-tomosynthesis-in-screening-approaches-to-reduce-reading-time (accessed May 13, 2023).

Section 02

Methodology

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Pipeline

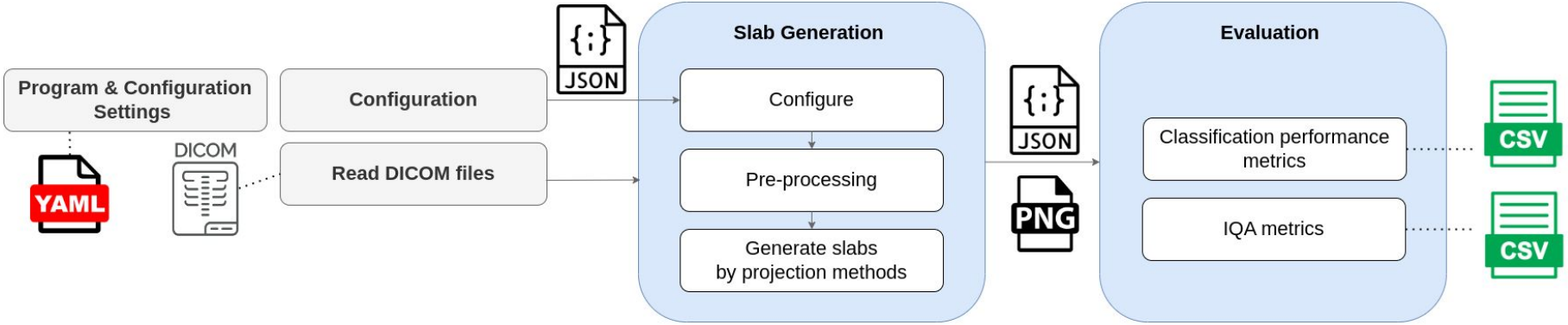


Figure 3. Pipeline schematic of the project

Dataset

Dataset of Breast Cancer Screening - DBT [3]

Training dataset with boxes indicating lesion locations

- normal
- actionable
- biopsy-proven benign - boxes
- biopsy-proven cancer - boxes

Required pre-processing [4]

[3] M. Buda, A. Saha, R. Walsh, S. Ghate, N. Li, A. Święcicki, J. Y. Lo, M. A. Mazurowski, Detection of masses and architectural distortions in digital breast tomosynthesis: a publicly available dataset of 5,060 patients and a deep learning model. (https://doi.org/10.1001/jamanetworkopen.2021.19100).
[4] https://github.com/mazurowski-lab/duke-dbt-data

Program Settings

Data Management

- Data directories
  - Config directory
  - Input directory
  - Output directory
- Bit-depth: 16

Evaluation

- IQA metrics:
  - CNR
  - Contrast
- Classification performance metrics:
  - Accuracy
  - Sensitivity
  - Specificity
  - AUC
  - Youden

Configurations

Slab Generation Parameters

- Projection method: MIP, AIP, Soft MIP
- Thickness: 6, 8, 10, 12, 14
- Overlap: 0%, 50%
- Breast skin removal: Yes, No

Configuration #: 60

Volume #: 1880

Slab images #: > 1 million

Encoding method: SHA-256 algorithm

projection method	mip / aip / soft mip
thickness	6
overlap	0 / 3
breast skin removal	no / yes

⋮

projection method	mip / aip / soft mip
thickness	14
overlap	0 / 7
breast skin removal	no / yes

Projection Methods

MIP $f_w^{MIP}(x) = 1 \; if \; x = 1, \; else \; 0$

AIP $f_w^{AIP}(x) = 1$

Soft MIP $f_w^{softMIP}(x) = x^4$

Create projection line: $P_s(x), \; 0 \leqslant x \leqslant l$
$P_s(0) = min(P), \; P_s(l) = max(P).$

Compute projection: $p = \frac{1}{\int_0^1 f_w(x)\,dx} \int_0^1 f_w(x)\, P_s(x)\, dx$

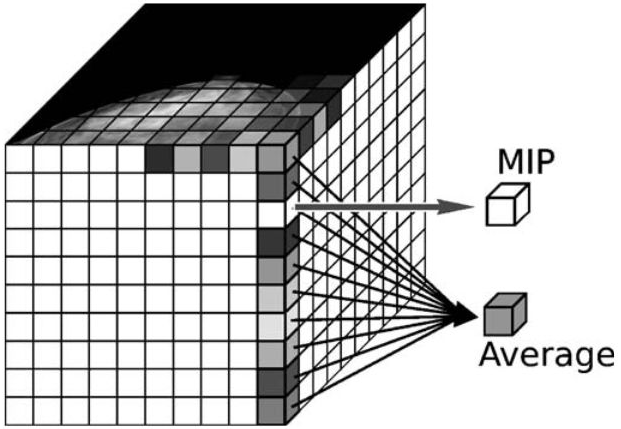


Figure 4. Maximum intensity projection and average intensity projection [5]

[5] F. Diekmann, H. Meyer, S. Diekmann et al., "Thick Slices from Tomosynthesis Data Sets: Phantom Study for the Evaluation of Different Algorithms," *Journal of Digital Imaging*, vol. 22, no. 5, pp. 519-526, Oct. 2009, doi: 10.1007/s10278-007-9075-y.

Evaluation Methods

Image Quality Assessment Metrics

- Contrast
- Contrast-to-noise ratio

No-reference methods without background annotations.

Classification Performance Metrics

- Accuracy
- Sensitivity
- Specificity
- AUC ROC
- Youden

Binary classification

Image Quality Assessment Metrics

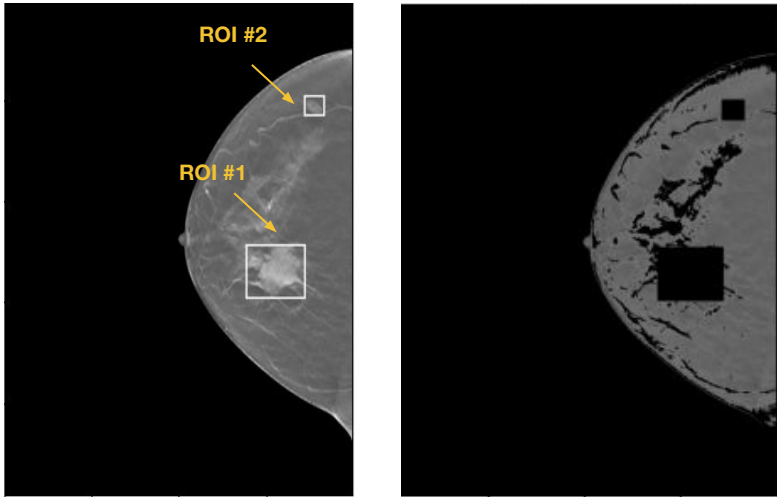


Figure 5. Background region and region of interests (ROI).

Contrast

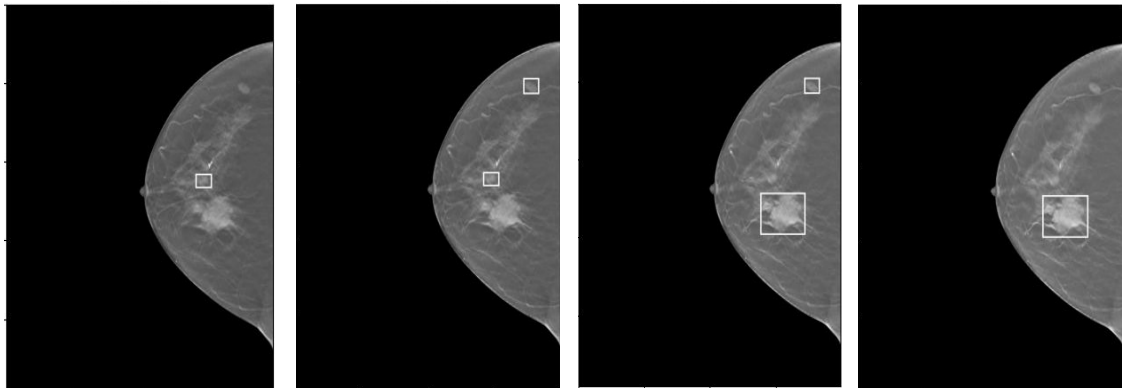
$$C = \frac{\left(\overline{P_1} - \overline{P_2}\right)}{\left(\overline{P_1} + \overline{P_2}\right)}$$

Contrast-to-noise ratio

$$CNR = \frac{\left(\overline{P_1} - \overline{P_2}\right)}{\sqrt{\sigma^2_{\overline{P_1}} + \sigma^2_{\overline{P_2}}}}$$

P_1 : *pixel values of the ROI*
P_2 : *pixel values of the background*

Segmenting ROIs



Slab #5 Slab #6 Slab #7 Slab #8

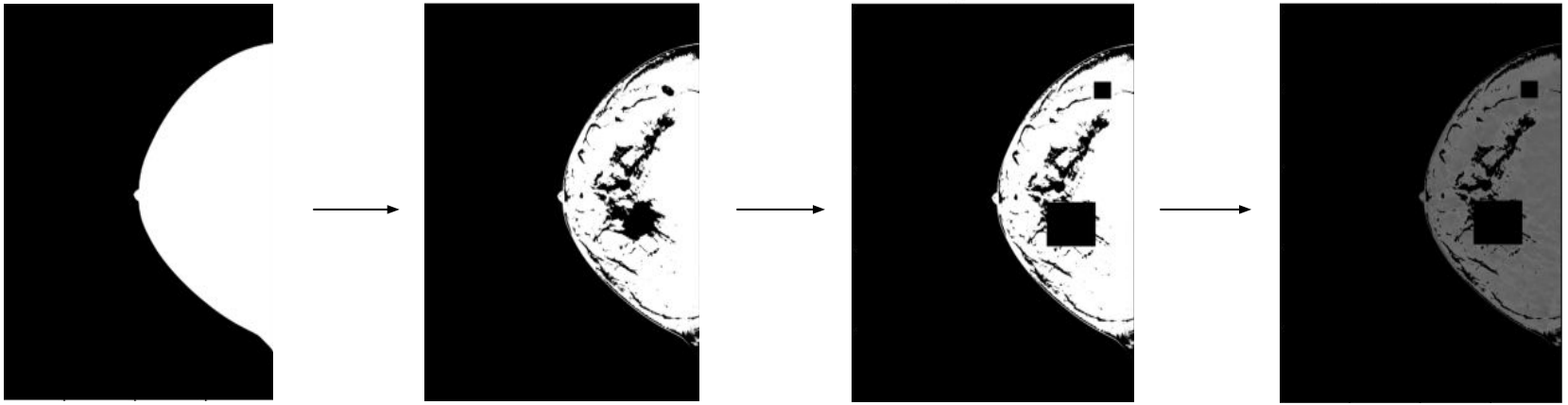
Figure 6. Slab images with ROIs

projection method	mip
thickness	14
overlap	7
breast skin removal	no

Table 1. Sample x- and y-coordinates of ROIs

slice	x1	x2	y1	y2
#21	1411	1535	1080	1172
#26	1713	1834	478	583
#29	1380	1724	1216	1487

Segmenting Background Region



Breast segmentation

Background segmentation with Li thresholding

Subtract ROIs from mask

Background image

Figure 7. Background segmentation steps.

Classification Performance Metrics

$$accuracy = ACC = \frac{TP + TN}{TP + FP + TN + FN}$$

$$sensitivity = TPR = \frac{TP}{TP + FN}$$

$$specificity = TNR = \frac{TN}{TN + FP}$$

$$J = sensitivity + specificity - 1$$

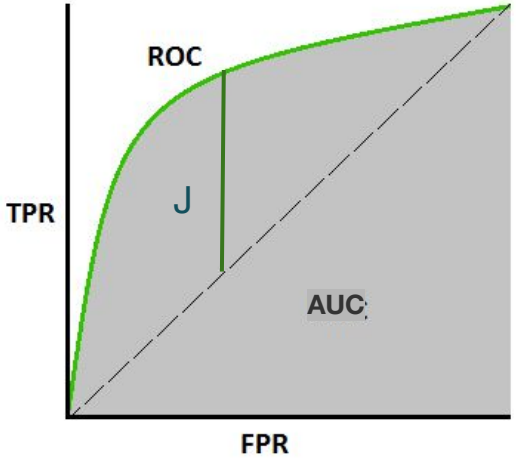


Figure 8. Area under the ROC Curve and Youden's J statistic [6].

[6] https://towardsdatascience.com/understanding-auc-roc-curve-68b2303cc9c5

Section 03

Results

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Dataset

Classification Performance

Normal: 1680

Actionable: 715

Benign: 124

Cancer: 76

Total: 1880

Image Quality Assessment

Benign: 124

Cancer: 76

Total: 200

Labels

Positive: cancer

Negative: normal or benign

Results

Classification Performance Results

- Best sensitivity and specificity with Youden > 0.5
- Selecting top prediction results: top 1, top 2, top 3
- Metrics are *average* for each configuration.

IQA Results

- *Mean* value of CNR and contrast are computed for each volume.

Remark: Slabs with AIP are missing!

Classification Performance Results

	Sensitivity (Youden>0.5)		Specificity (Youden>0.5)		Youden		AUC	
Best	projection method	soft mip	projection method	mip	projection method	soft mip	projection method	soft mip
	thickness	14	thickness	10	thickness	6	thickness	8
	overlap	7	overlap	0	overlap	0	overlap	0
	breast skin removal	1	breast skin removal	0	breast skin removal	0	breast skin removal	1
	top	3	top	2	top	1	top	2
	metric value	0.9211	metric value	0.9645	metric value	0.6707	metric value	0.8761
Worst	projection method	soft mip	projection method	mip	projection method	mip	projection method	mip
	thickness	14	thickness	6	thickness	6	thickness	10
	overlap	0	overlap	3	overlap	3	overlap	5
	breast skin removal	1	breast skin removal	1	breast skin removal	1	breast skin removal	0
	top	3	top	1	top	1	top	1
	metric value	0.1184	metric value	0.0349	metric value	0.0349	metric value	0.8420

IQA Results

	CNR	
Best	**projection method**	**mip**
	thickness	14
	overlap	7
	breast skin removal	1
	metric value	3.774 ∓ 0.026346
Worst	**projection method**	**soft mip**
	thickness	10
	overlap	0
	breast skin removal	1
	metric value	0.0014 ∓ 0.0

	Contrast	
Best	**projection method**	**mip**
	thickness	12
	overlap	6
	breast skin removal	1
	metric value	0.258 ∓ 0.000145
Worst	**projection method**	**soft mip**
	thickness	10
	overlap	0
	breast skin removal	1
	metric value	0.000064 ∓ 0.0

IQA Results

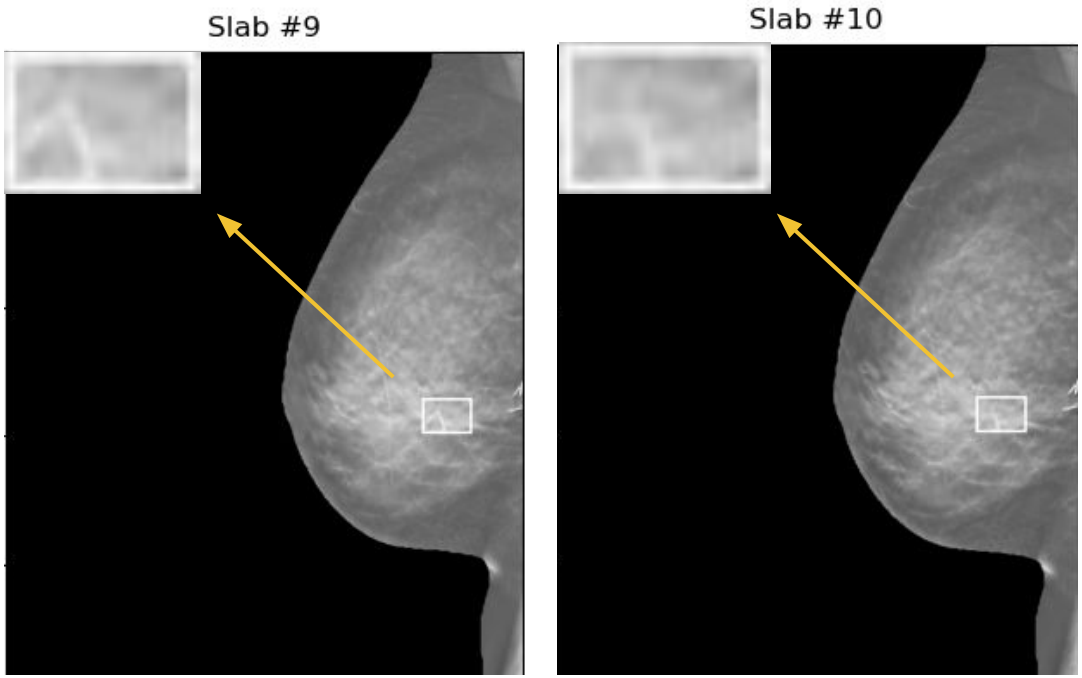

Figure 9. Best CNR (3.774) and contrast (0.258) results from the configuration giving best results.

IQA Results

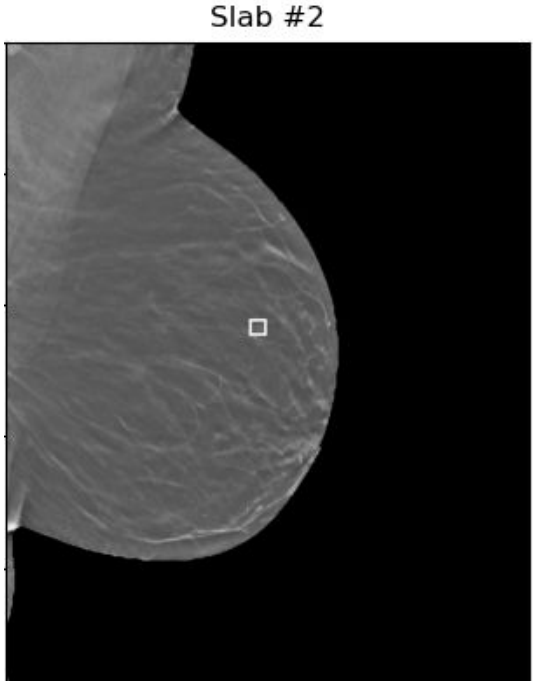

Figure 10. Worst CNR (0.0014) and contrast (0.000064) results.

Discussion

Classification Performance Results

- *Maximum Youden result:* Soft MIP, thin slabs, without overlap.
  But actually the sensitivity are low ~0.8.
- *Maximum sensitivity result:* Soft MIP, thick slabs, with overlap.
- *Best configuration results*: **Soft MIP** gives better results than MIP overall.
- *Not affected by breast skin removal.*

IQA Results

- *Best configuration results:* **MIP, thick slabs, with overlap**.
  Not affected by breast skin removal.

Section 04

Demo

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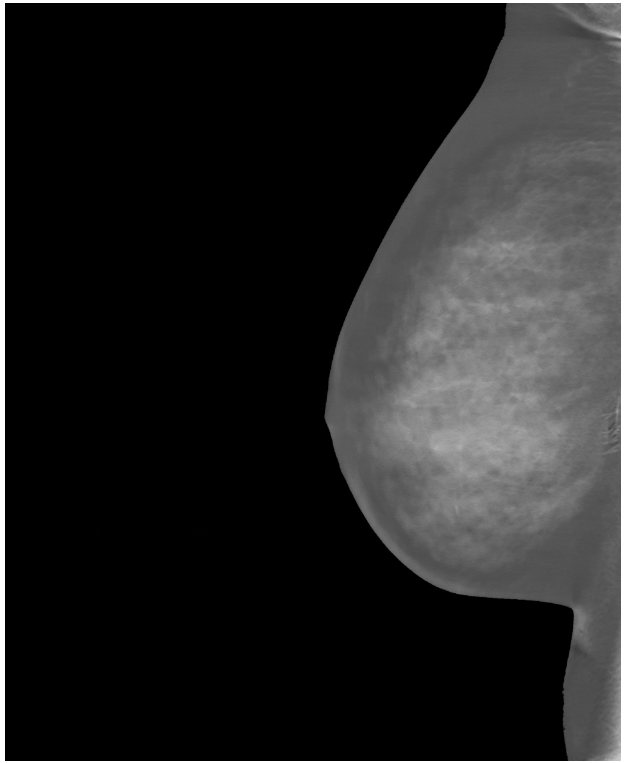
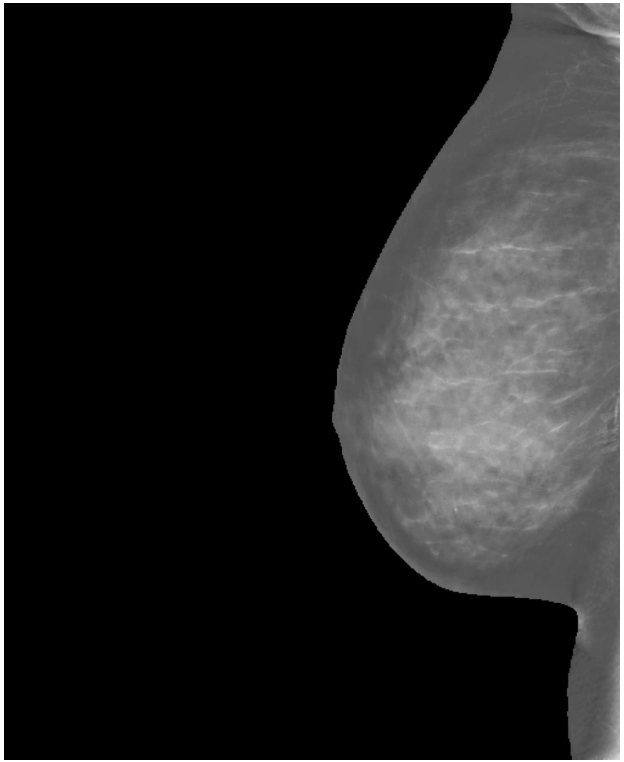
Slices



Slabs



Sample configuration

projection method	mip
thickness	14
overlap	7
breast skin removal	1

Section 05

Project Progress

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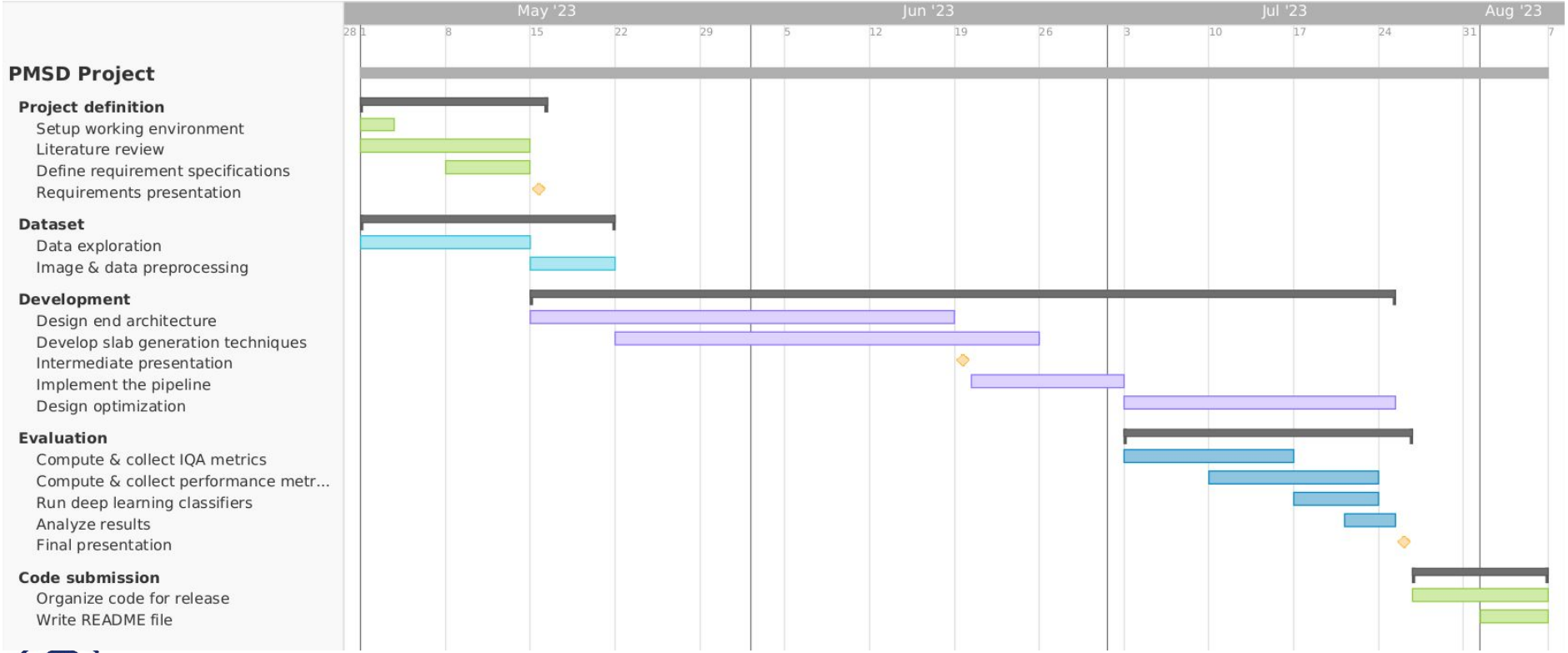
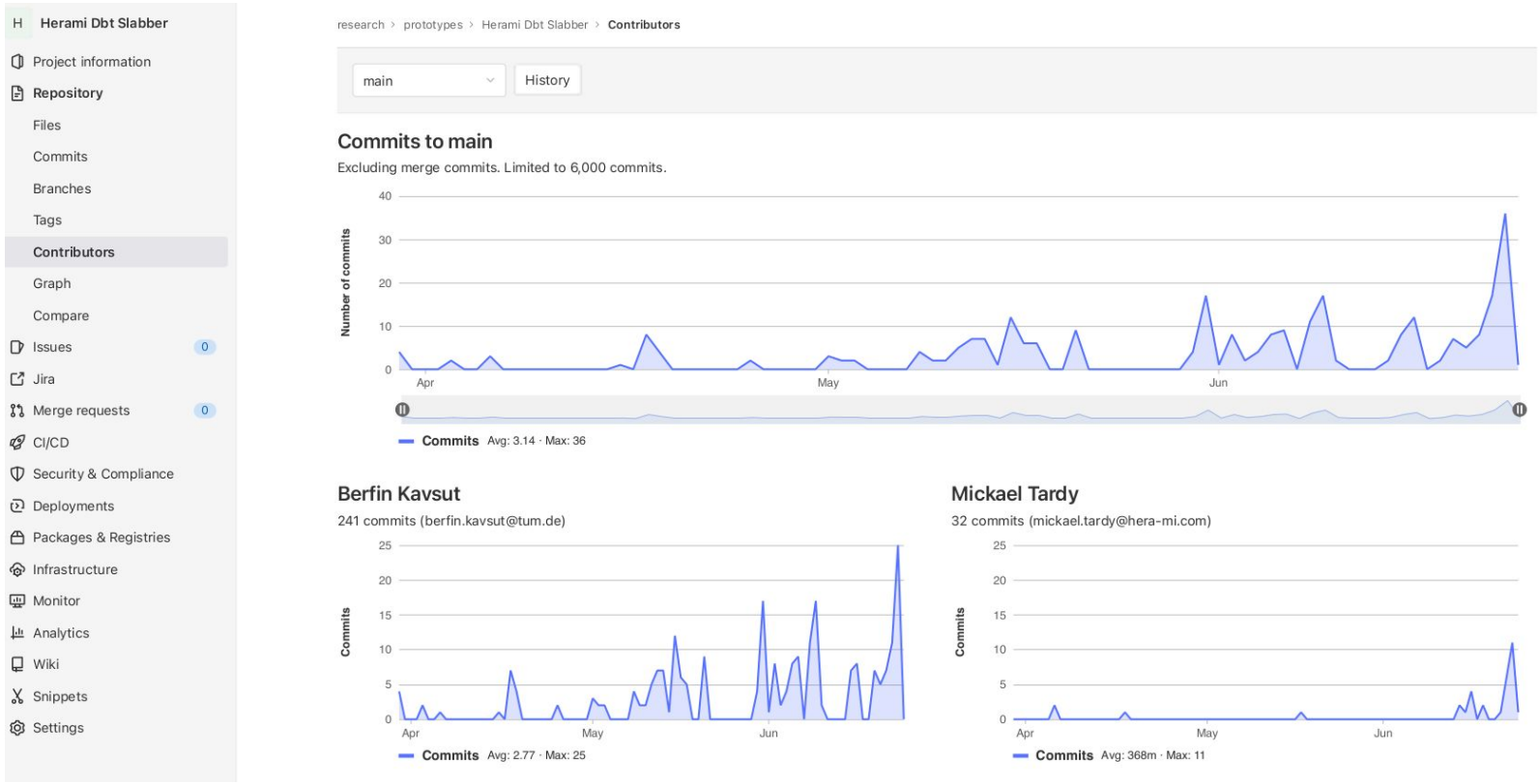
Final Gantt Chart



Git Commit History



Thank you!

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