A Deep Learning Classifier Using Sliding Patches for Detection of Mammographical Findings

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- Worldwide, has an average mortality rate of 13.6 per 100 000 women in 2020 [1]
- In Chile, has an average mortality rate of 11.8 per 100 000 women, as of 2018 [2]
- Early diagnosis and survival rate in Chile has increased due to the implementation of screening programs [3]

Figure: Mortality rate and number of potential lost years of life due to breast cancer in Chilean Women (2009-2018)

[1] *Breast Cancer Statistics | World Cancer Research Fund International*. WCRF International. URL: https://www.wcrf.org/cancer-trends/breast-cancer-statistics/ (visited on 11/09/2023)

[2] Ministerio de Salud. *Informe de Vigilancia de Cáncer. Análisis de Mortalidad Prematura y AVPP Por Cáncer. Década 2009-2018.* Chile: Departamento de Epidemiologia, 2021. URL: https://www.minsal.cl/wp-content/uploads/2022/01/Informe-Mortalidad-Prematura-y-AVPP-por-C%C3%A1ncer-2009-2018.pdf (visited on 11/09/2023)

[3] César del SM Castillo, M. Elena C. Cabrera, Lea Derio P., et al. "Resultados Del Tratamiento Del Cáncer de Mama, Programa Nacional de Cáncer Del Adulto". In: *Revista médica de Chile* 145.12 (Dec. 2017), pp. 1507–1513. ISSN: 0034-9887. DOI: 10.4067/s0034-98872017001201507. URL: https://scielo.conicyt.cl/scielo.php?script=sci_abstract&pid=S0034-98872017001201507&lng=es&nrm=iso&tlng=en (visited on 04/21/2021)

- Machine Learning and Deep Learning models have been implemented for the detection of breast cancer in mammograms. [4]
- Current Challenges:
  - Detection of breast lesion location in mammograms [5]
  - Visualisation tools for interpretation of prediction models.

[4] Alejandro Rodríguez-Ruiz, Elizabeth Krupinski, Jan-Jurre Mordang, et al. "Detection of Breast Cancer with Mammography: Effect of an Artificial Intelligence Support System". In: *Radiology* 290.2 (Nov. 20, 2018), pp. 305–314. ISSN: 0033-8419. DOI: 10.1148/radiol.2018181371. URL: https://pubs.rsna.org/doi/10.1148/radiol.2018181371 (visited on 05/12/2021)

[5] O. Díaz, A. Rodríguez-Ruiz, A. Gubern-Mérida, et al. "¿Son los sistemas de inteligencia artificial una herramienta útil para los programas de cribado de cáncer de mama?" In: *Radiología* 63.3 (May 2021), pp. 236–244. ISSN: 00338338. DOI: 10.1016/j.rx.2020.11.006. URL: https://linkinghub.elsevier.com/retrieve/pii/S0033833820301752 (visited on 03/30/2023)

Ertosun and Rubin proposed a Deep Learning model for visual search in mammograms using a regional probabilistic approach.
[6]

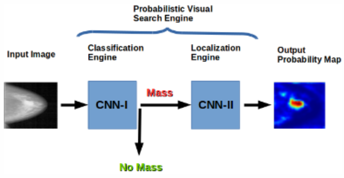

Figure: Probabilistic Visual Search Engine proposed by Ertosun and Rubin

[6] Mehmet Gunhan Ertosun and Daniel L. Rubin. "Probabilistic Visual Search for Masses within Mammography Images Using Deep Learning". In: *2015 IEEE International Conference on Bioinformatics and Biomedicine (BIBM)*. 2015 IEEE International Conference on Bioinformatics and Biomedicine (BIBM). Washington, DC, USA: IEEE, Nov. 2015, pp. 1310–1315. ISBN: 978-1-4673-6799-8. DOI: 10.1109/BIBM.2015.7359868. URL: http://ieeexplore.ieee.org/document/7359868/ (visited on 11/09/2023)

[7] Steven J. Frank. "A Deep Learning Architecture with an Object-Detection Algorithm and a Convolutional Neural Network for Breast Mass Detection and Visualization". In: *Healthcare Analytics* 3 (Nov. 1, 2023), p. 100186. ISSN: 2772-4425. DOI: 10.1016/j.health.2023.100186. URL: https://www.sciencedirect.com/science/article/pii/S2772442523000539 (visited on 11/09/2023)

[8] Darvin Yi, Rebecca Lynn Sawyer, David Cohn III, et al. *Optimizing and Visualizing Deep Learning for Benign/Malignant Classification in Breast Tumors*. May 17, 2017. arXiv: 1705.06362 [cs]. URL:

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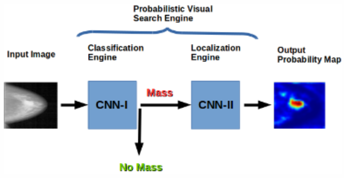

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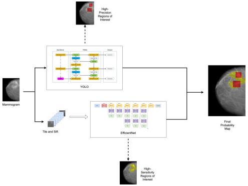

Figure: Combined detection model and classifier for breast cancer proposed by Frank

[6] Mehmet Gunhan Ertosun and Daniel L. Rubin. "Probabilistic Visual Search for Masses within Mammography Images Using Deep Learning". In: *2015 IEEE International Conference on Bioinformatics and Biomedicine (BIBM)*. 2015 IEEE International Conference on Bioinformatics and Biomedicine (BIBM). Washington, DC, USA: IEEE, Nov. 2015, pp. 1310–1315. ISBN: 978-1-4673-6799-8. DOI: 10.1109/BIBM.2015.7359868. URL: http://ieeexplore.ieee.org/document/7359868/ (visited on 11/09/2023)

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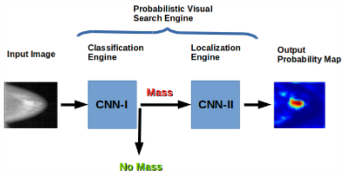

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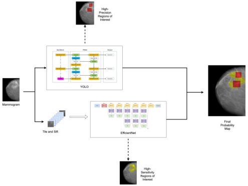

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Yi, Sawyer, Cohn III, et al. proposed a model for visualization of shared features between views of the breast for classification of benign and malignant breast tumours. [8]

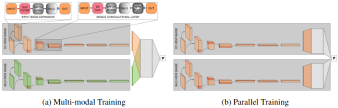

Figure: Multimodal architecture proposed by Yi, Sawyer, Cohn III, et al. for visualization of shared features between views of the breast.

[6] Mehmet Gunhan Ertosun and Daniel L. Rubin. "Probabilistic Visual Search for Masses within Mammography Images Using Deep Learning". In: *2015 IEEE International Conference on Bioinformatics and Biomedicine (BIBM)*. 2015 IEEE International Conference on Bioinformatics and Biomedicine (BIBM). Washington, DC, USA: IEEE, Nov. 2015, pp. 1310–1315. ISBN: 978-1-4673-6799-8. DOI: 10.1109/BIBM.2015.7359868. URL: http://ieeexplore.ieee.org/document/7359868/ (visited on 11/09/2023)

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Our study proposes a Deep Learning Classifier trained on cropped segments of mammograms for multi-label classification of pathological findings.
General Inspection of the complete image using local patches.

Dataset

- **Vindr-mammo** Dataset [9]
- 5000 digital mammogram examinations containing for each view:
  - BIRADs
  - Breast density
  - Bounding box of each finding present on the image
- 10 classes of pathological findings

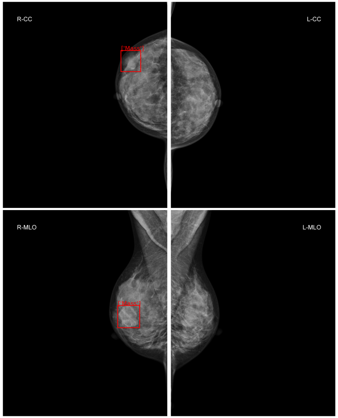


Figure: Example of a mammogram from the Vindr-mammo dataset.

[9] Hieu Huy Pham, Hieu Nguyen Trung, and Ha Quy Nguyen. *VinDr-Mammo: A Large-Scale Benchmark Dataset for Computer-Aided Detection and Diagnosis in Full-Field Digital Mammography*. Version 1.0.0. PhysioNet. DOI: 10.13026/BR2V-7517. URL: https://physionet.org/content/vindr-mammo/1.0.0/ (visited on 11/08/2022)

Dataset Distribution

- Each DICOM Image is normalised to a range of [0, 1]
- Apply CLAHE algorithm [10] for histogram equalization at 2 different scales
- Fuse the equalized images with the original, channel-wise
- Image is cropped to the bounding box of the breast using Otsu's thresholding.

[10] S.M. Pizer, R.E. Johnston, J.P. Ericksen, et al. “Contrast-Limited Adaptive Histogram Equalization: Speed and Effectiveness”. In: *[1990] Proceedings of the First Conference on Visualization in Biomedical Computing*. [1990] Proceedings of the First Conference on Visualization in Biomedical Computing. May 1990, pp. 337–345. DOI: 10.1109/VBC.1990.109340. URL: https://ieeexplore.ieee.org/document/109340 (visited on 10/03/2023)

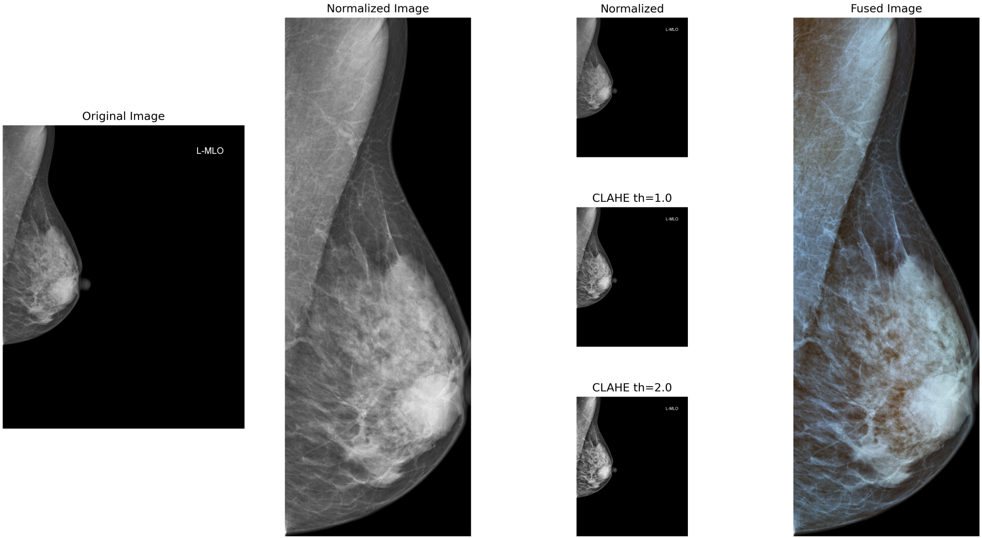


Figure: Image processing pipeline

We evaluated the following architectures as a backbone:

- ResNet50
- EfficientNetV2 [10]
- DenseNet
- Swin Transformer
- MobileNet
- VGG19

Classifier Layer using 2 layer MLP with 512 hidden units and ReLU activation. Output layer with 10 units and sigmoid activation.

- We use the backbone of the selected architecture as a feature extractor.
- The output of the backbone is flattened and fed to the classifier.
- The classifier is trained using the cropped images.

- For each finding present on an image, we sampled a random area of the finding.
- Area and aspect ratio randomly sampled from an Uniform distribution.
  - Area: [.05, 5.] of the finding bounding box area.
  - Aspect ratio: [0.33, 1.66] of the finding bounding box aspect ratio.
  - The bounding box center is uniform sampled from 50 px around the original center.
- For normal images (*No Finding*), we sample a random area of the breast, with similar sampling parameters.
- Sampled image is resized to 256×256 pixels.
- **Image augmentation**: Contrast, brightness, saturation, flip and rotation are randomly modified.

Example of sampling

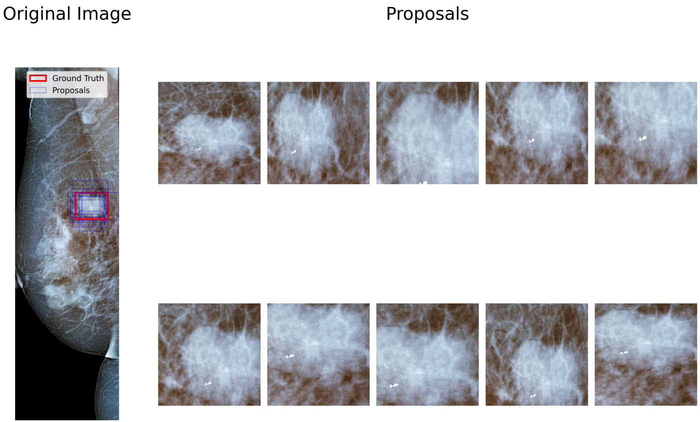


Figure: Example of sampling of ten positive proposals from a finding.

- Focal Loss Function

$$\mathcal{L}_{\text{Focal}} = -(1 - p_t)^{\gamma} \log(p_t)$$

- Adam Optimizer with a starting learning rate of 1×10^{-4}
- Reduce on plateau with a patience of 5 epochs and a factor of 0.1
- Weighted sampling of the dataset, in order to reduce imbalance.

- Segmentation of the complete image into a set of overlapping windows of size 256×256 pixels and stride of 32 px.
- Reconstruction of prediction heatmap from the overlapping windows.

Table: F1 Score for Pathological findings classification task with Vindr, comparing different Deep Learning Models.

	N	DenseNet	EfficientNet	ResNet50	SwinTransformer	VGG19	MobileNet
Mass	237	0.783	0.815	0.742	0.770	0.756	0.708
Suspicious Calcification	115	0.847	0.865	0.860	0.828	0.873	0.828
Assymetries	79	0.306	0.295	0.200	0.310	0.204	0.324
Suspicious Lymphonode	11	0.667	0.500	0.737	0.370	0.400	0.476
Weighted Average	442	0.712	**0.727**	0.675	0.693	0.679	0.665

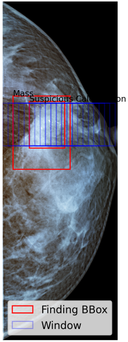
EfficientNet has the best overall performance, with an F1 score of 0.727. We chose this model as the backbone for our classifier.

Table: Metrics of pathological findings classification task using Vindr

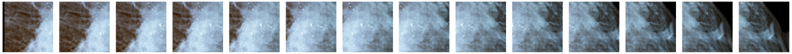
	Accuracy	Precision	Recall	F1	Support
No Finding	0.978	0.991	0.984	0.988	3643
Mass	0.970	0.743	0.730	**0.736**	237
Suspicious Calcification	0.990	0.805	0.861	**0.832**	115
Focal Asymmetry	0.983	0.200	0.094	0.128	53
Architectural Distortion	0.993	0.222	0.083	0.121	24
Asymmetry	0.995	0.000	0.000	0.000	20
Suspicious Lymph Node	0.998	0.625	0.455	0.526	11
Skin Thickening	0.998	1.000	0.333	0.500	12
Nipple Retraction	0.998	0.000	0.000	0.000	7
Global Asymmetry	0.998	0.000	0.000	0.000	6
Skin Retraction	0.999	0.500	0.333	0.400	3

Our model achieves a weighted Accuracy of 93.80 % and a weighted F1 score of 0.9557

Evaluated Image



Predictions



No Finding	5.0%	4.0%	1.8%	1.2%	0.8%	1.2%	1.7%	3.6%	4.1%	6.4%	12.2%	19.5%	32.3%	45.3%
Mass	35.0%	44.1%	50.2%	55.9%	53.8%	58.0%	46.1%	46.5%	49.5%	43.5%	33.2%	25.7%	25.9%	19.5%
Suspicious Calcification	57.4%	59.6%	56.4%	56.4%	53.7%	51.9%	67.4%	55.9%	65.6%	63.5%	60.3%	44.6%	19.1%	6.3%
Assymetries	2.7%	2.5%	1.8%	1.7%	2.1%	2.6%	3.4%	11.1%	29.3%	48.8%	62.4%	57.0%	53.3%	37.7%
Architectural Distortion	2.9%	3.7%	4.0%	2.5%	2.1%	1.0%	0.8%	1.3%	1.9%	2.6%	4.3%	5.8%	7.7%	5.5%
Suspicious Lymph Node	5.2%	3.4%	1.0%	0.5%	0.3%	0.5%	0.5%	0.8%	0.8%	1.4%	2.1%	3.0%	10.0%	10.3%
Skin Thickening	9.8%	7.4%	2.8%	1.4%	0.9%	1.3%	2.2%	5.5%	3.3%	3.8%	4.1%	5.9%	12.8%	16.4%
Retractions	11.7%	12.9%	8.2%	4.2%	1.3%	0.8%	0.9%	2.6%	4.0%	6.1%	7.7%	11.7%	13.9%	13.3%

Figure: Image with bounding boxes of its findings and prediction of a row of local windows using our classifier.

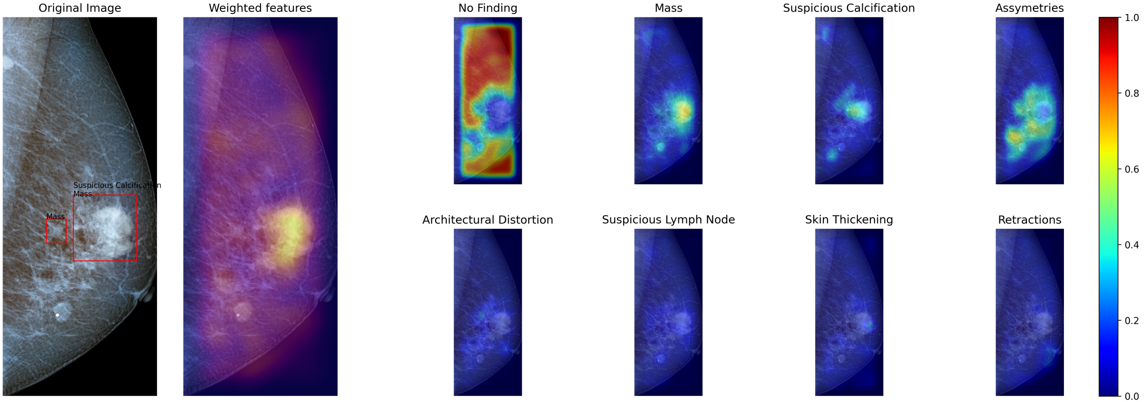


Figure: Cropped test image with bounding boxes of its findings, feature activation heatmap, and prediction of the classifier.

Effects of scale of window

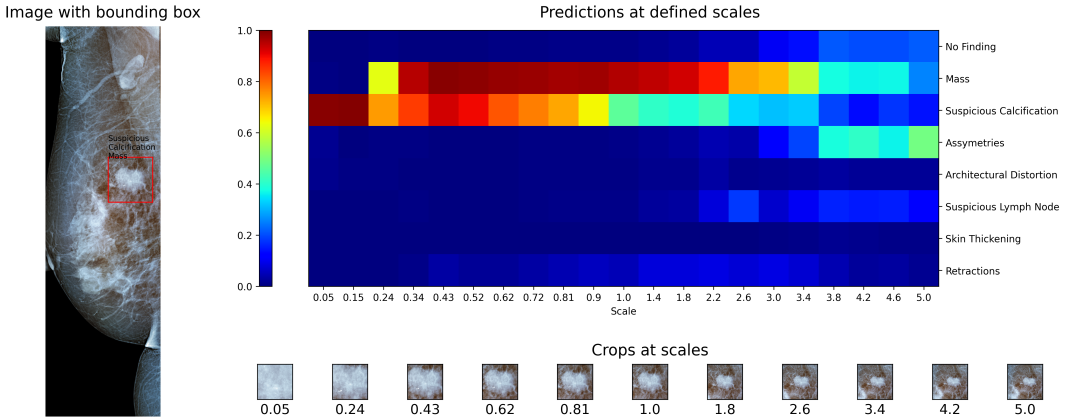


Figure: Prediction of classifier, using finding at different scales.

Limitations

- Low availability of data for some classes impact performance on certain findings.
- High sensitivity of the model to the size of findings.
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Our model is able to identify findings present in unknown data.

Discussion

Future Work

References I

[1] *Breast Cancer Statistics | World Cancer Research Fund International*. WCRF International. URL: https://www.wcrf.org/cancer-trends/breast-cancer-statistics/ (visited on 11/09/2023).

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