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Preoperative prediction of lymph node metastasis from clinical DCE MRI of the primary breast tumor using a 4D CNN

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Deep Learning for
Precision Health Lab

www.utsouthwestern.edu/labs/montillo

Outline

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Breast cancer clinical procedure

- Breast cancer's 5 years survival rate is only 27% . The presence of lymph node metastasis is the most important prognostic factor.

- Radiologists often use Ultrasound and MRI to diagnose metastasis of lymph node, results in clinical Node status or cNode.

- If cNode is positive, the patient will have to go through resection or biopsy.

- We believe image of the primary tumor has information of metastasis status.
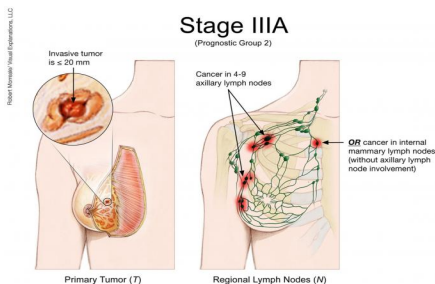
cNode status in breast cancer

- cNode status is critical in choosing treatments for patients and crucial affect to outcome

- In this study, we consider cNode status belong to {N0, N+} which mean negative and positive metastasis

- A high sensitivity cNode prediction is desirable because false positive may result in uncaptured spread and 90% of breast cancer deaths are from spread to other parts of the body.

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Materials

- Clinical 1.5T DCE MRI of 357 breast cancer patients with invasive breast cancer from two hospitals: UTSouthwestern Medical Center and Parkland with two different MRI machines GE and Philips.

- We collect four clinical features: Age, ER, HER2, and Ki67.

- Ground truth of cNode status was determined by radiologists.

Table: Demographics and disease characteristic of subjects included in this analysis.

Variable	Age							cNode status				Tumor stage			
Category	21-30	31-40	41-50	51-60	61-70	71-80	81-90	N0	N1	N2	N3	T1	T2	T3	T4
Percentage	2	16	34	23	19	5	1	62	28	4	6	30	44	19	7
Number of patients	7	57	121	82	68	18	4	221	101	13	22	107	157	68	25

Data pre-processing

- Input are subtracted DCE MRI of the primary tumor, voxelwise cropped time3-time1, time4-time1, time5-time1
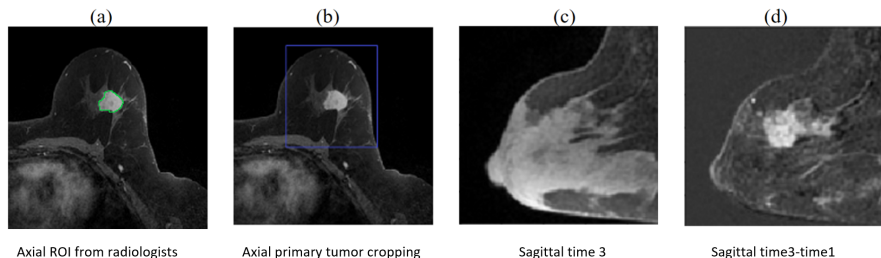
Figure: Preprocessing the volumetric DCE MRI. (a) primary tumor is radiologist delineated at time3 in each slice (green contour), (b) MRI is cropped to a cuboidal volume around tumor, (c) sagittal view showing breast at time1, (d) tumor is enhanced by computing difference images, shown here: time3-time1.

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Data partitioning and augmentation

- Group 10-fold partitioning, with 2 held out set, 1 for validation, the other one for testing.

- Augmentation: random rotation, random cropping, random noise, increase the data to 30x.

- We use weighted cost function to handle imbalanced data

$$E = \frac{1}{N} \sum_{k=1}^{N} \sum_{c=1}^{2} (p_c^k - l_c^k)^2 \cdot w_c \tag{1}$$

where N is number of training samples, c is class index, p^k is output of kth training sample, l^k is label of kth training sample, and w_c is weight of class c.

Hybrid 4D CNN model

- We develop different models corresponding with increasing number of data dimensions. We have clinical only, 2D CNN, 3D CNN, 4D CNN and 4D CNN hybrid model (combine DCE MRI and clinical data)
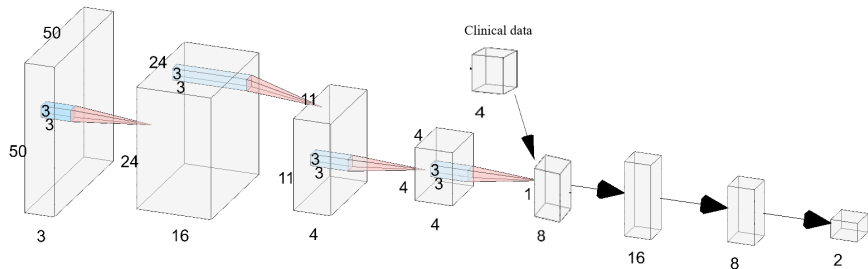

Figure: The 4D CNN hybrid model architecture.
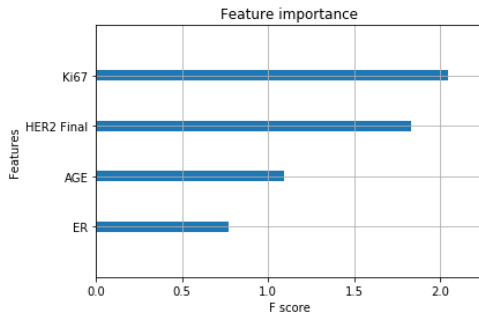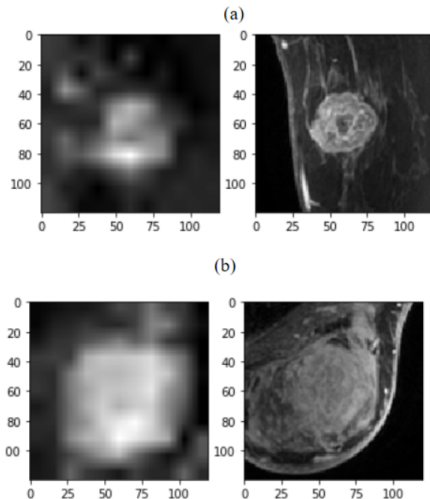
(*)one data dimension is omitted

Results

Result of testing our hypothesis

Clinical only		2D image		3D image		4D image		**4D img & clinical**	
AUC	TPR	AUC	TPR	AUC	TPR	AUC	TPR	**AUC**	**TPR**
0.55	0.24	0.61	0.35	0.66	0.84	0.67	0.72	**0.71**	**0.72**

Features importance from clinical only model

GradCAM result

Discussion

- Difference between hospital data is currently mitigated through preprocessing. Using a scanner agnostic model could be helpful.

- Unsupervised pretraining on external data may improve performance

- Additional MRI contrasts could be added such as T2, ADC

- Current method assumes minimal motion between MRI time frames, we will apply motion correction in the future.

Conclusion

- Demonstrate that MRI image of primary tumor has information for metastasis prediction.

- Saliency mapping shows that the model used tumor and peritumoral voxels to predict auxilla metastasis.

- Results are promising, look forward to presenting more results in the future.

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