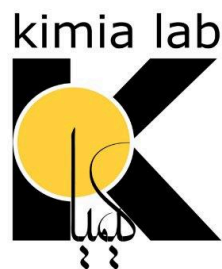




CNN and Deep Sets for End-to-End Whole Slide Image Representation Learning

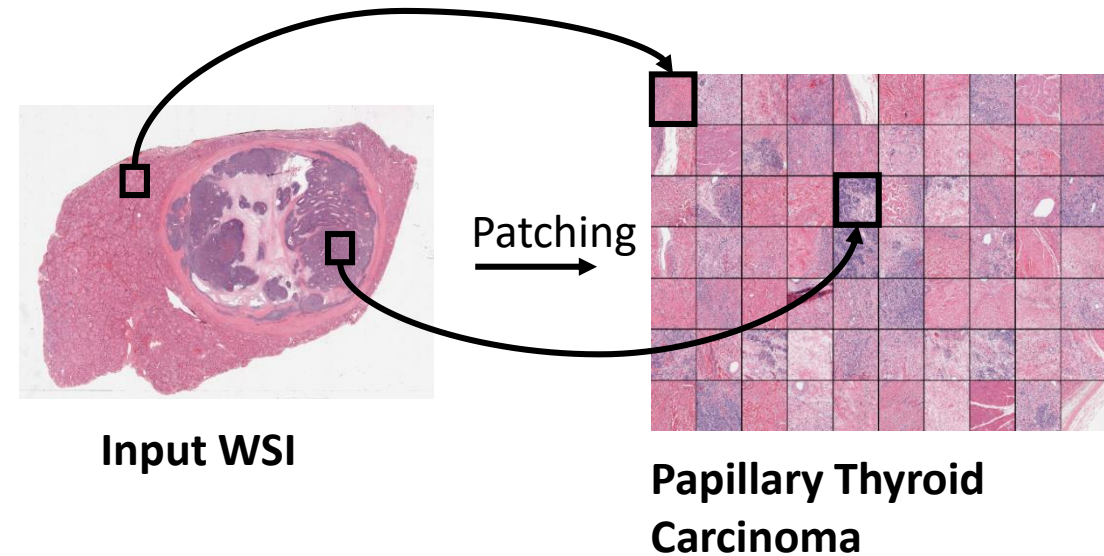
Sobhan Hemati, Shivam Kalra, Cameron Meaney, Morteza Babaie, Ali Ghodsi, Hamid R. Tizhoosh

Presenter - Sobhan Hemati



Problem Definition:

- We cannot feed WSIs to neural nets due to their gigantic size.
- Typical solution is patch extraction:

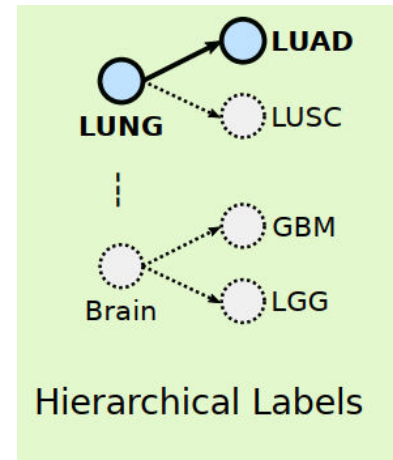


- **Input:** A set of patches.
- **Output:** Primary site and Cancer sub-type.

Problem Definition

Whole Slide Image (WSI) Representation Learning

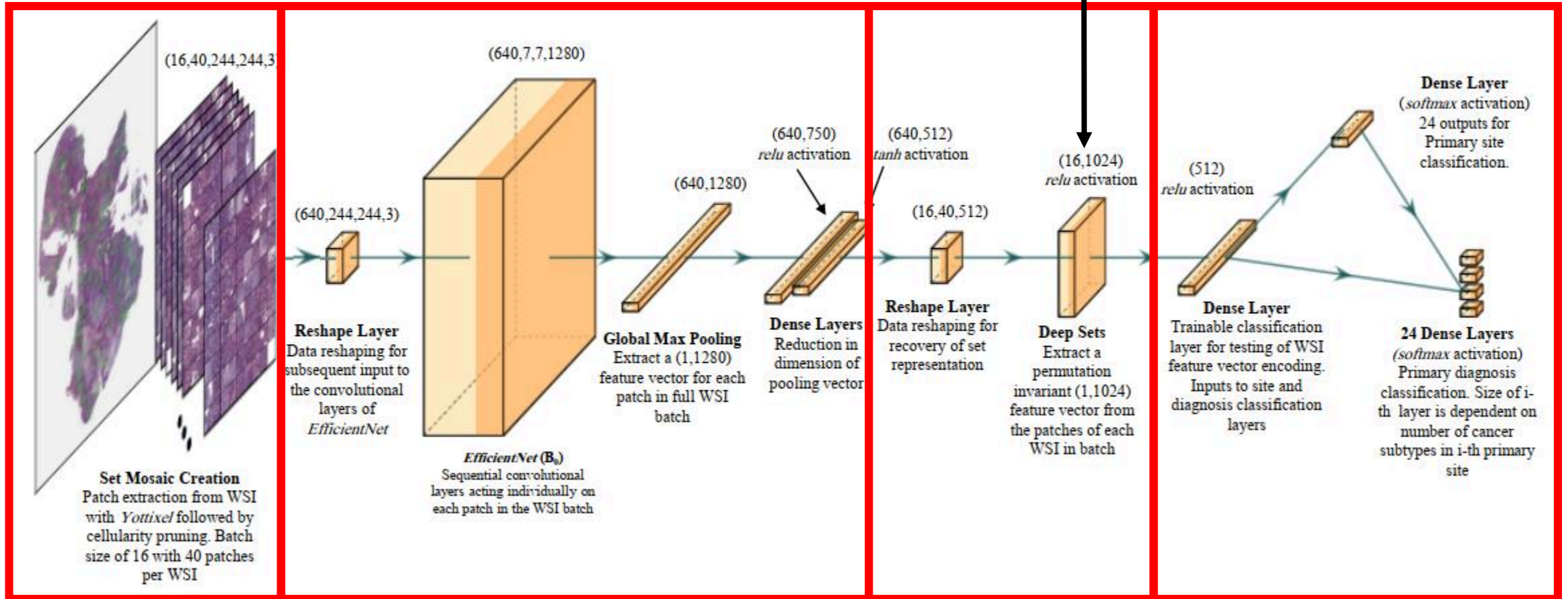
- Patch labels are not available
- Training on patches gives us nothing more than patch embeddings.
- Downstream tasks are not straightforward:
- Some proposed solutions:
 - WSI classification with patch embeddings: Decision fusion methods
 - WSI (set) search with patch embeddings: Heuristic methods
- There is a hierarchy between labels.



We need WSI (set) embedding- Our model should process set data i.e., be permutation invariant and acknowledge dependency between WSI labels.

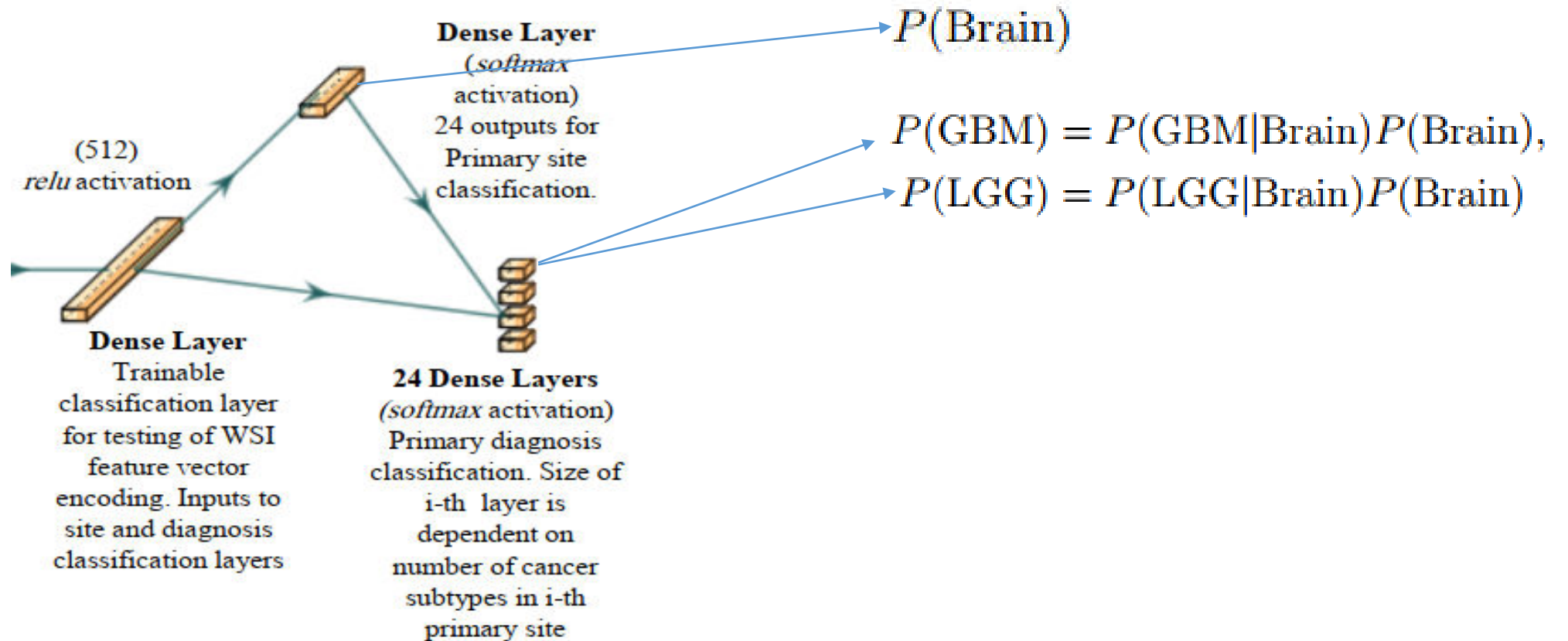
CNN-Deep Sets

$\rho(\text{pool}(\{\phi(x_1), \dots, \phi(x_n)\}))$
universal approximator of set functions



CNN-Deep Sets

- Hierarchical multi-label training:



Experiments: WSI search- Horizontal search

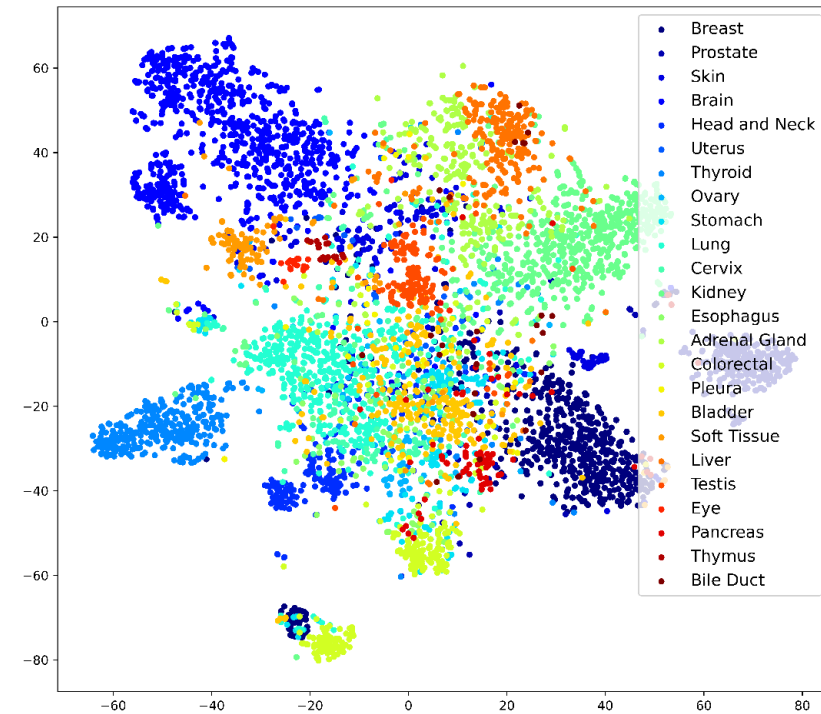
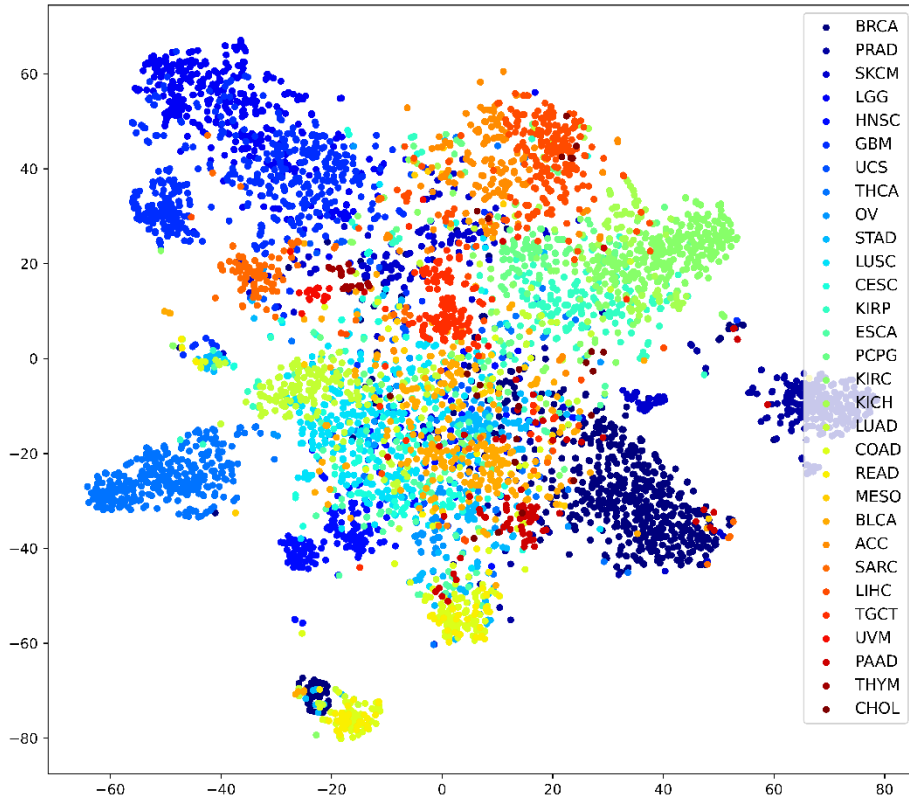


Table 1: Majority-3 and 5 search accuracy (%) for the horizontal search (primary site identification) among 604 WSIs for Yottixel and CNN Deep Sets (best results in green).

Tumor Type	Patient #	Accuracy (in %)			
		Yottixel ($k = 3$)	CNN-DS ($k = 3$)	Yottixel ($k = 5$)	CNN-DS ($k = 5$)
Brain	46	73	91	73	89
Breast	77	45	77	38	79
Endocrine	71	61	66	59	62
Gastro.	69	50	75	49	74
Gynaec.	18	16	33	0	27
Head/neck	23	17	69	13	65
Liver	44	43	56	36	43
Melanocytic	18	16	50	5	38
Mesenchymal	12	8	100	0	83
Prostate/testis	44	47	81	43	77
Pulmonary	68	58	91	54	89
Urinary tract	112	67	76	62	74

Experiments: WSI search- Vertical search

Table 2: Majority-3 and -5 search through k -NN for the vertical search among 604 WSIs. Best F1-measure values highlighted.



Site	Subtype	n_{slides}	F1-measure (in %)			
			Yottixel	CNN-DS	Yottixel	CNN-DS
Brain	LGG	23	78	89	75	81
	GBM	23	82	89	83	84
Endocrine	THCA	50	92	98	91	98
	ACC	6	25	28	28	0
	PCPG	15	61	81	61	79
Gastro.	ESCA	10	12	44	25	55
	COAD	27	62	69	54	70
	STAD	22	61	64	57	78
	READ	10	30	55	16	0
Gynaeco.	UCS	3	75	80	50	50
	CESC	6	92	66	76	80
	OV	9	80	82	66	82
Liver, panc.	CHOL	4	26	0	25	0
	LIHC	32	82	95	87	95
	PAAD	8	94	94	77	94
Prostate/testis	PRAD	31	98	97	95	96
	TGCT	13	96	93	86	93
Pulmonary	LUAD	30	62	61	62	61
	LUSC	35	69	60	69	62
	MESO	3	0	50	0	0
Urinary tract	BLCA	31	89	95	86	94
	KIRC	47	91	87	89	84
	KIRP	25	75	84	79	81
	KICH	9	70	53	66	0

Histopathology Image Classification

Table 3: CNN-DS evaluation on lung cancer classification via transfer learning.

Algorithm	Accuracy (in %)
Coudray et al. (Coudray et al., 2018)	85
Kalra & Adnan et al. (Kalra et al., 2020a)	84
Khosravi et al. (Khosravi et al., 2018)	83
Yu et al. (Yu et al., 2016)	75
CNN-DS (Ours)	86

Conclusion

- CNN-Deep Sets for end-to-end WSI representation learning.
- New hierarchical multi-label training that acknowledge dependency between primary site and its corresponding primary diagnosis labels.
- Attractive results in WSI search and classification.