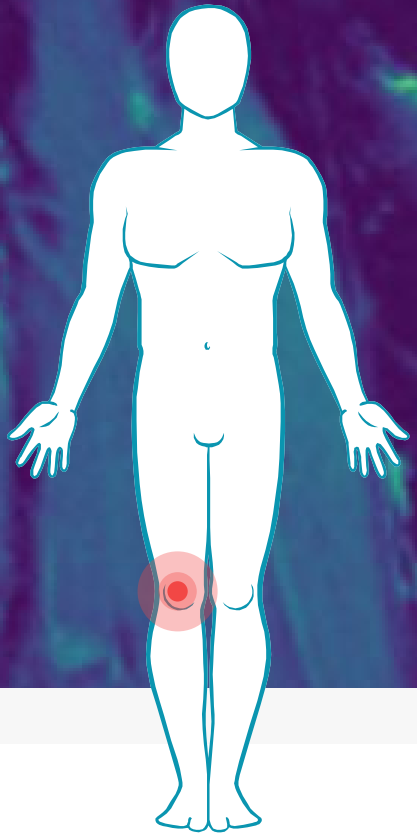
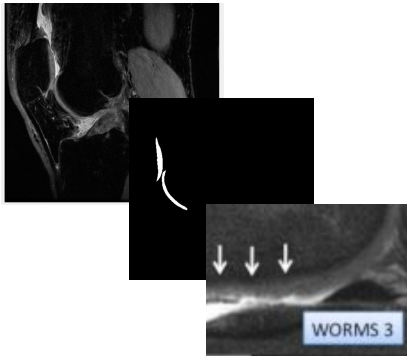
UCSF Department of Radiology and Biomedical Imaging

CartilageX: Automated anomaly detection in knee MRIs



Iriondo C, Jain D, Muhamedrahimov R, Papanikolaou V, Trotskovsky K, Sun L

Knee Pain Affects 25% Of Adults

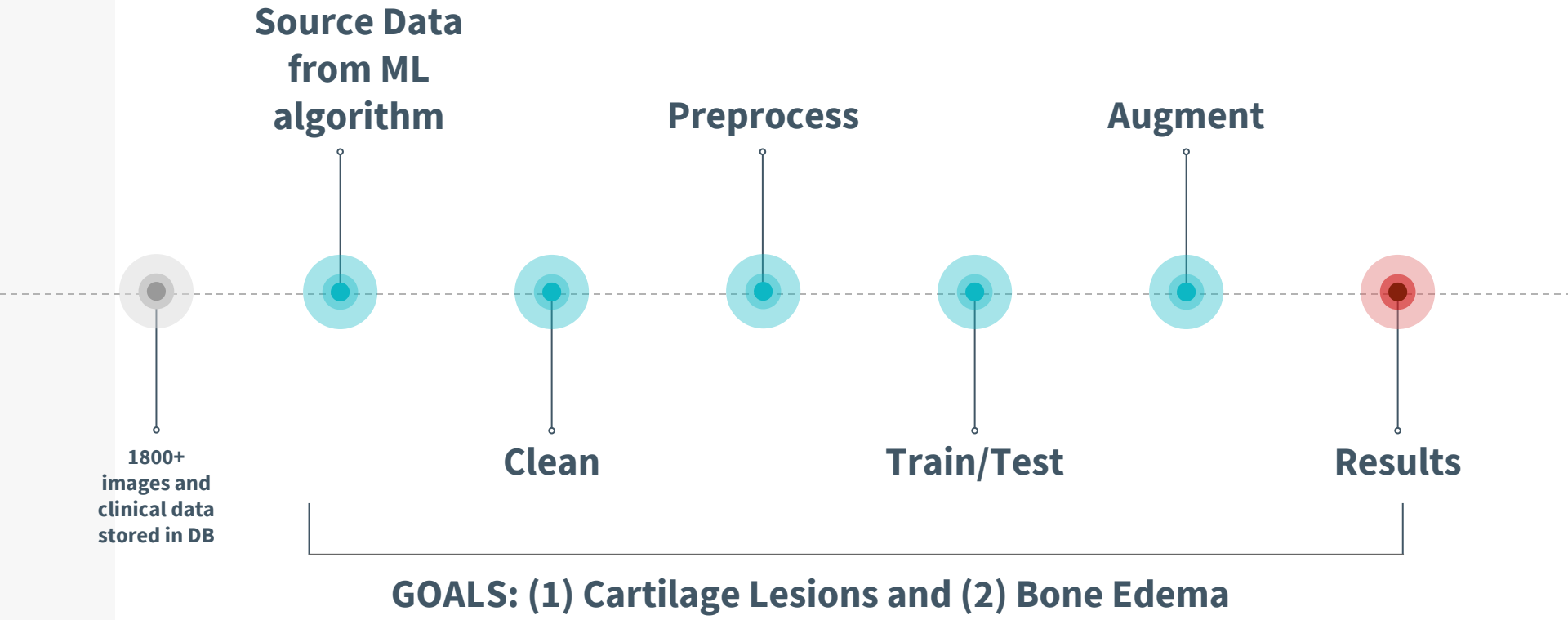


Pain → MRI scan → Segmentation & grading → Treatment

AI-guided diagnosis for the development of personalized treatment plans for knee injuries and pathologies

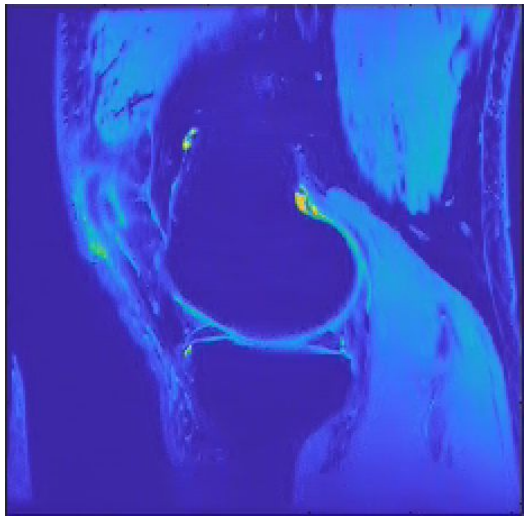
1.1 Billion USD market opportunity

Model Development

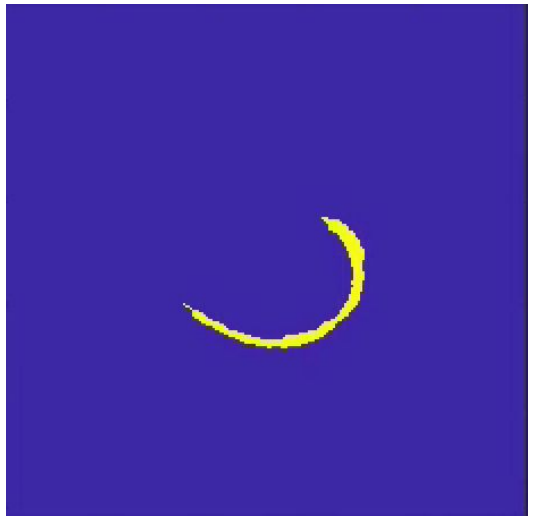


GOAL 1: Cartilage Lesions

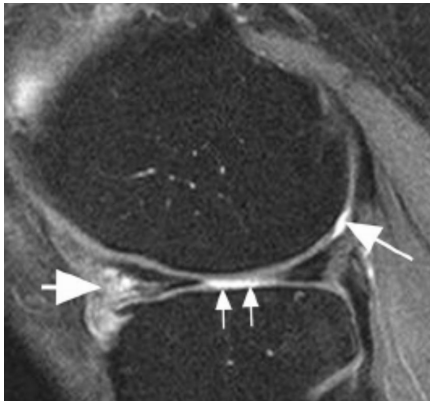
3D MRI image



3D Segmentation Mask



Signal of interest:

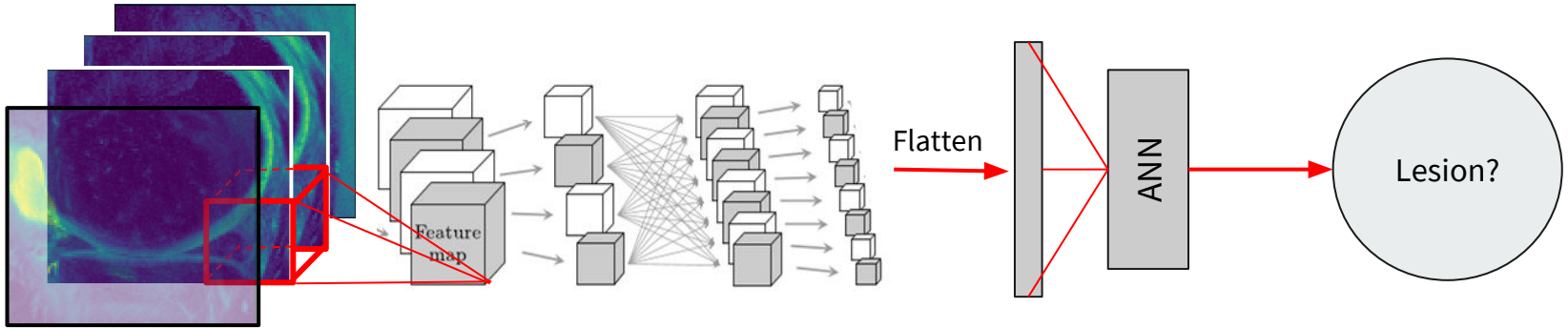


Thickness defects in cartilage surface

Score: [0 1] Healthy

[2 2.5 3 4 5 6] Cartilage Lesion

Classifying Cartilage Lesions with 3D CNN



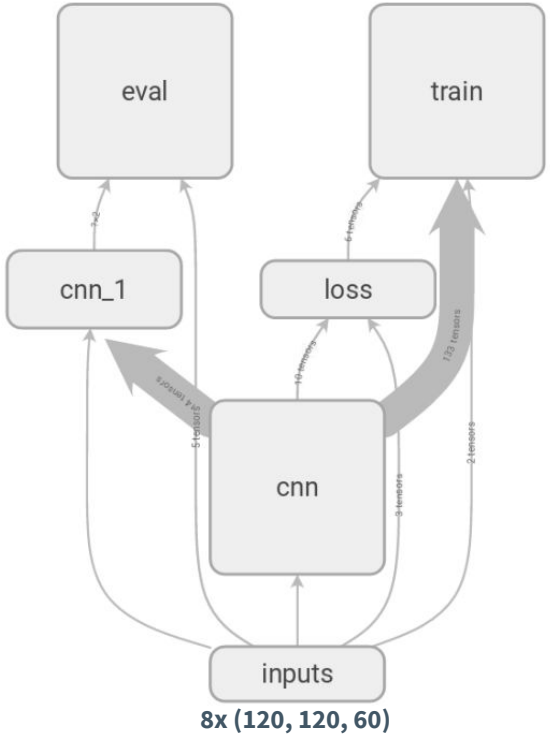
MRI volumes
(512, 512, 224)

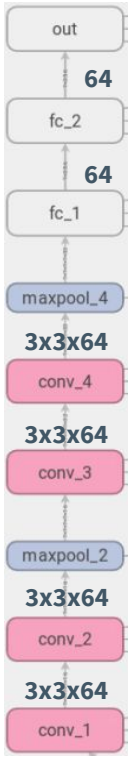
3D convolutions for feature extraction

1D feature map for classification

Classification

Lesion Classification Results

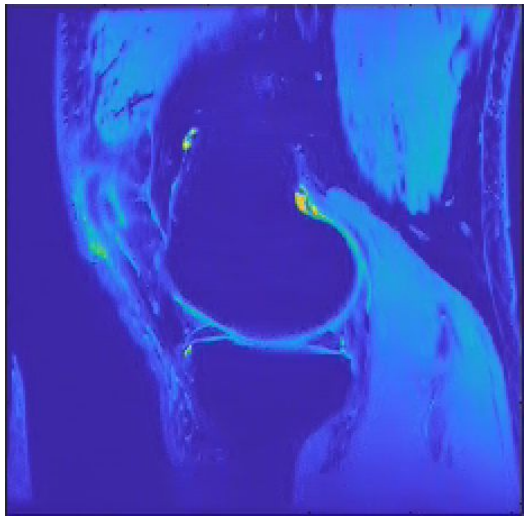




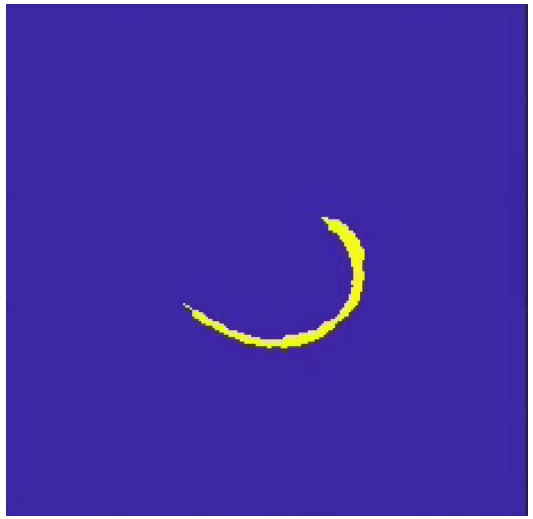
	Full Training Set (0.8)	Validation Set (0.2)
Accuracy	**0.86**	**0.75**
Recall	**0.93**	**0.61**
Precision	**0.50**	**0.28**

GOAL 2: Bone Marrow Edema

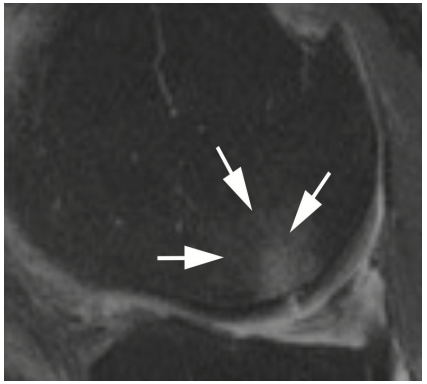
3D MRI image



3D Segmentation Mask



Signal of interest:



Hyper-intese zones in bone directly above cartilage

Score:

[0] Healthy

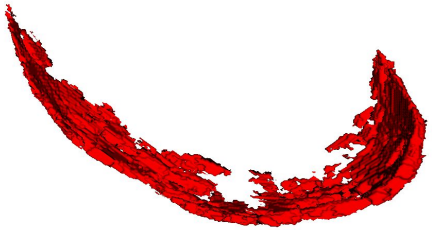
[1 2 3] Bone Marrow Edema

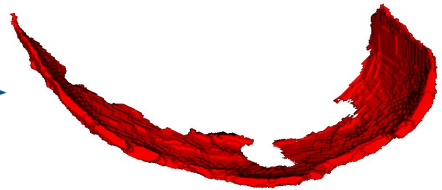
Improving Performance by Image Flattening

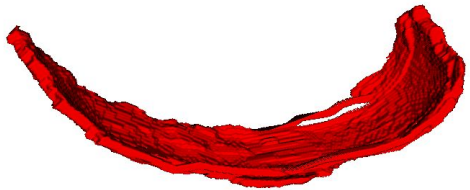
Segmentation from Unet

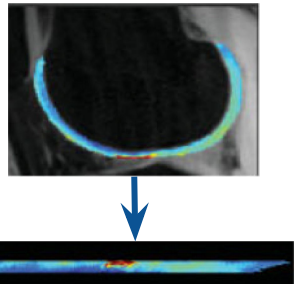
Superposition and dilation

Morphological closing

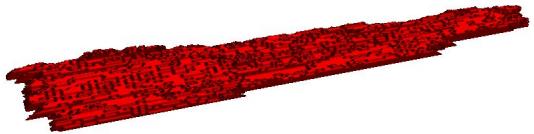






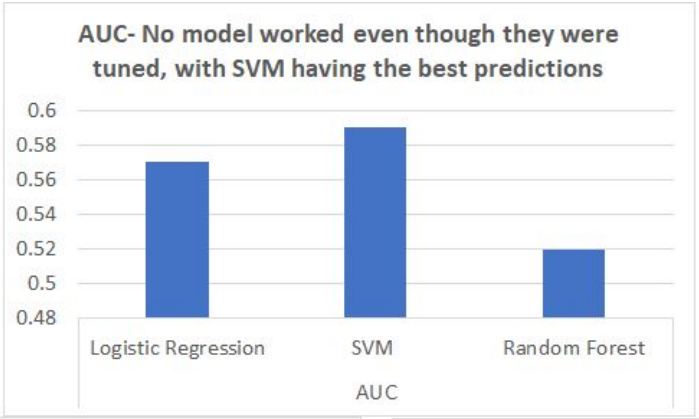


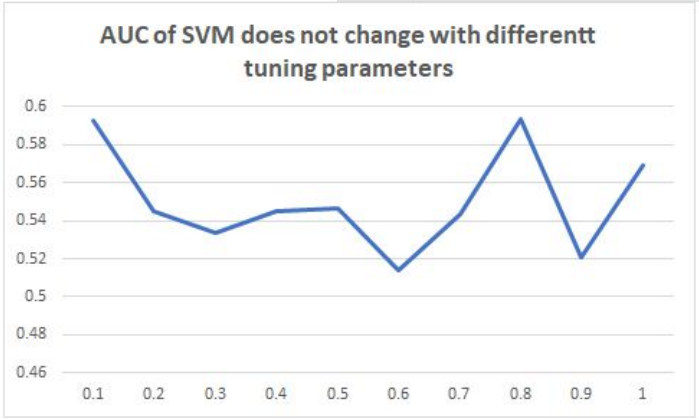
↑ signal of interest-to-background ratio
preservation of cartilage volume
↓ input size by 6x (200,150,30)→(250,20,30)

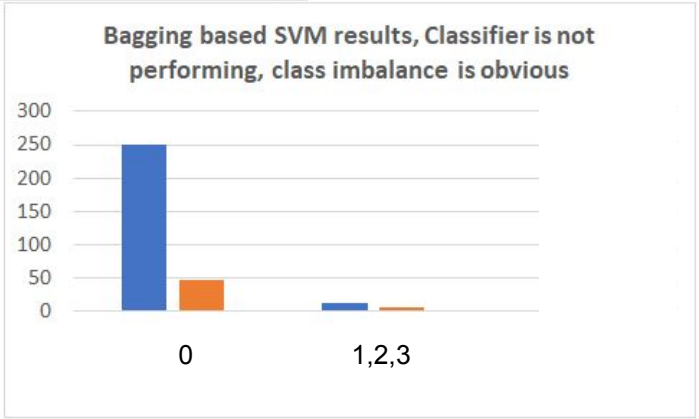


Flattening

Edema Classification using Classic ML





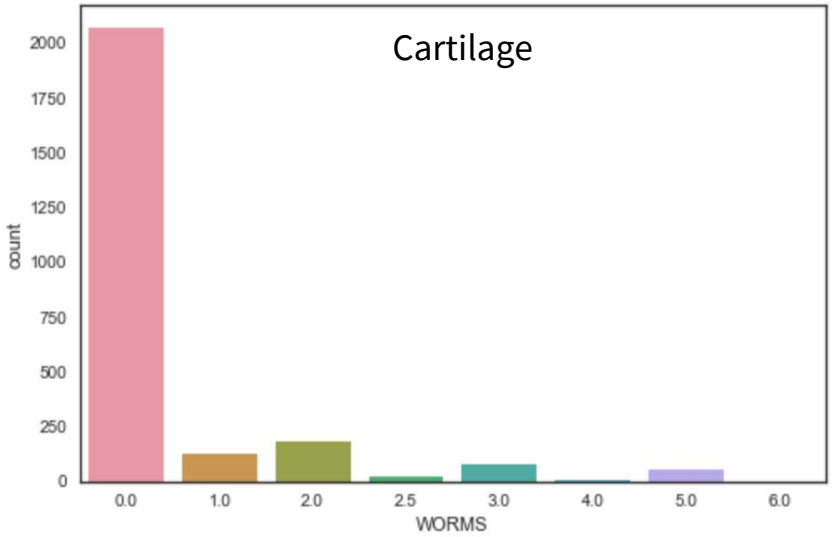


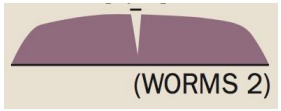
Edema Classification with 2D CNN

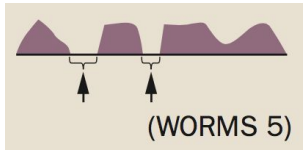
Keras (Tensorflow wrapper) with 80/20 Train-test split

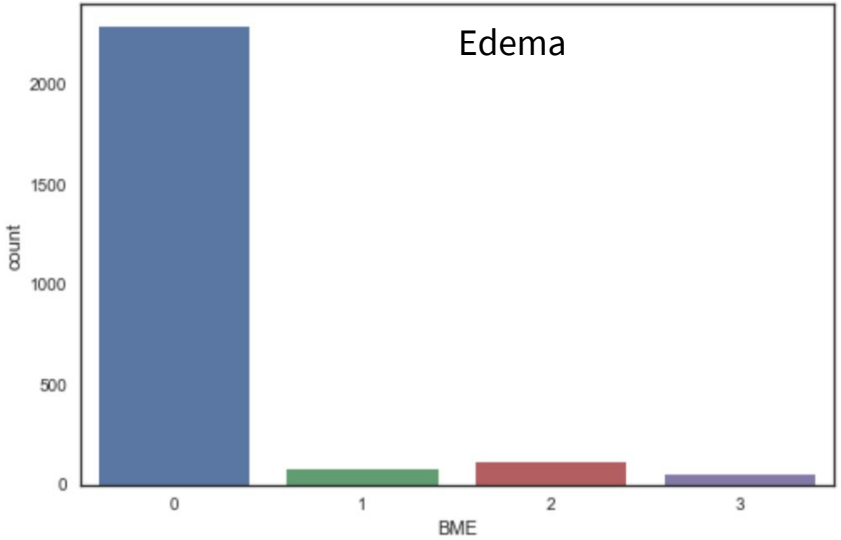
N = 1700 +2x minority	30 Epochs (Test)	30 Epochs (Validation)	*N = 1585 +1x minority*	15 Epochs (Test)	15 Epochs (Validation)
Confusion Matrix	[249 , 4] [46 , 37]	[1179, 0] [0 , 219]	Confusion Matrix	[287 , 3] [17 , 1]	[1141, 1] [53 , 80]
Accuracy	85.1%	100%	Accuracy	93.5%	95.7%
Precision	0.90	1	Precision	0.85	.98
Recall	0.45	1	Recall	0.05	.60

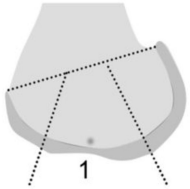
Motivation for Data Augmentation

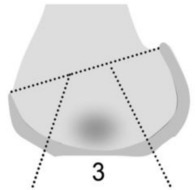




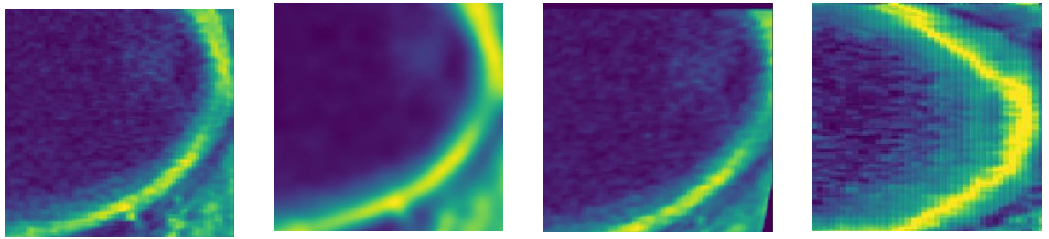








Data Augmentation Techniques + 2D CNN Results



N = 3010 +2x minority	Baseline performance	Filters (Gaussian, median)	Affine transformations	Intensity variations
Confusion Matrix	[1201, 0] [104, 0]	[277, 0] [28, 10]	[302, 0] [34, 77]	[311, 0] [26, 40]
Validation Precision	**0**	**1**	**1**	**1**
Validation Recall	**0**	**0.26**	**0.69**	**0.61**

Improvements

Data Preprocessing	• Establish quality guidelines for images/segmentations to run flattening and projection algorithms • Extract cartilage features directly from the flattened images and try a simpler and faster classifier • Create multi-plane projection images (sagittal, coronal, axial)
Cartilage Lesions	• Optimize 3D-CNN, iterate through more model architectures • Online batch sampling to tackle class imbalance and improve consistency of training • Transfer learning: pre-train model on balanced dataset, initialize new model using trained weights • Alternative models, including recurrent convolutional neural networks • Introduce demographic features (age, BMI, gender) in last layer of network
Bone Marrow Edema	• Optimize 2D-CNN architecture (number of layers, filter size, weighted sampling) • Train the net with combined data augmentations (affine + filter, affine + intensity, etc) • Implement multi-class classification with BME score • Implement LIME to visualize activation map of CNN and lesion location
Data Augmentation	• Conduct principal component analysis (PCA) on the images to identify the components that are indicative of cartilage or bone lesions, alter non-significant components to generate synthetic instances • Apply data augmentation on volumes for 3D CNN

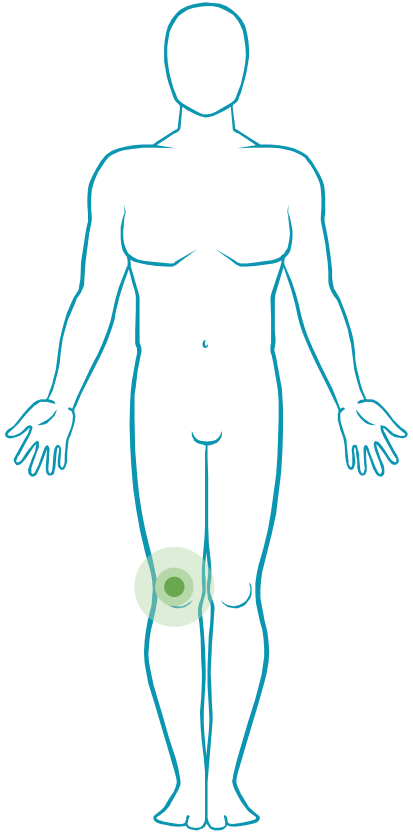
Next Steps

Improvements for stability

- Data curation
- Model performance
- Testing generalizability with new dataset

Product strategy

- Investigate deployment opportunities
- US focused roll-out
- FDA 510(k), risk of de-novo



Thanks to our mentors:
Kevin Li, Valentina Pedoia, & UCSF MQIR

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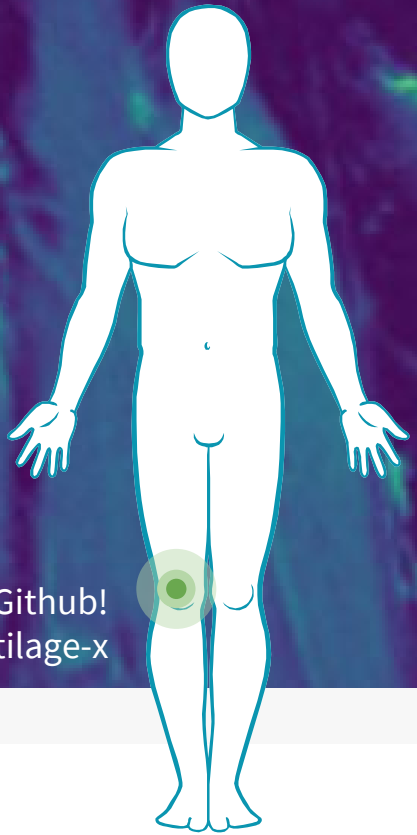

Github!
/raoufmuh/cartilage-x

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Precision and Recall

How many images classified as lesions were actually lesions?

How many lesions of the total were detected?