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Gleason Grade Group Prediction for Prostate Cancer Patients with MR Images Using Convolutional Neural Network

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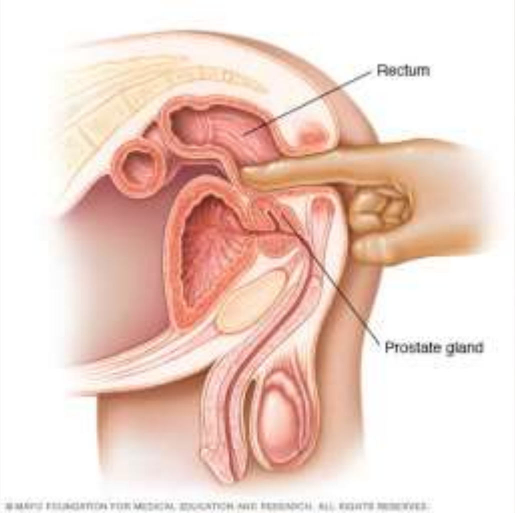
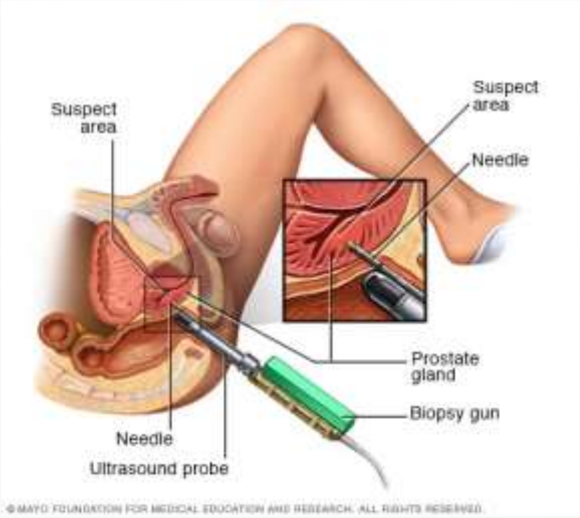
Introduction

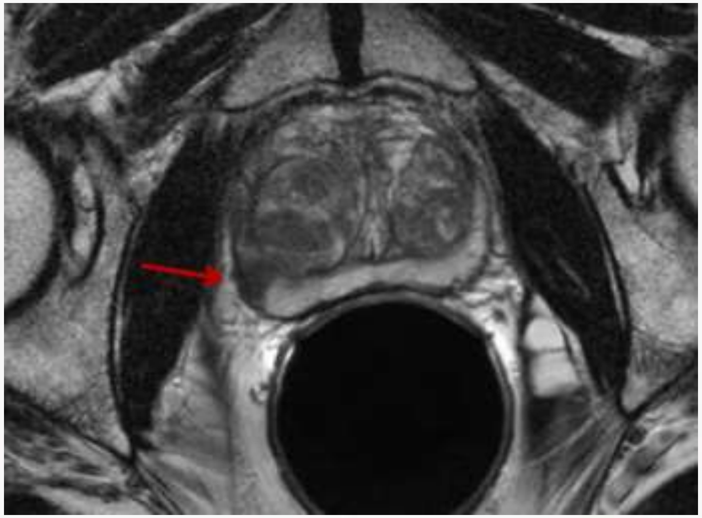


- Prostate CA is the most common malignancy in men.
  - An accurate diagnosis requires a **tissue biopsy**.
- Can we eliminate this need?
  - Differentiating prostate CA from benign tissue on imaging:
  - Literature: AUC of **0.87**. Our experience: AUC of **0.90**.
- Can we predict the Gleason grade group?
  - Literature: AUC of **0.50**.
  - **Can we improve upon this**?



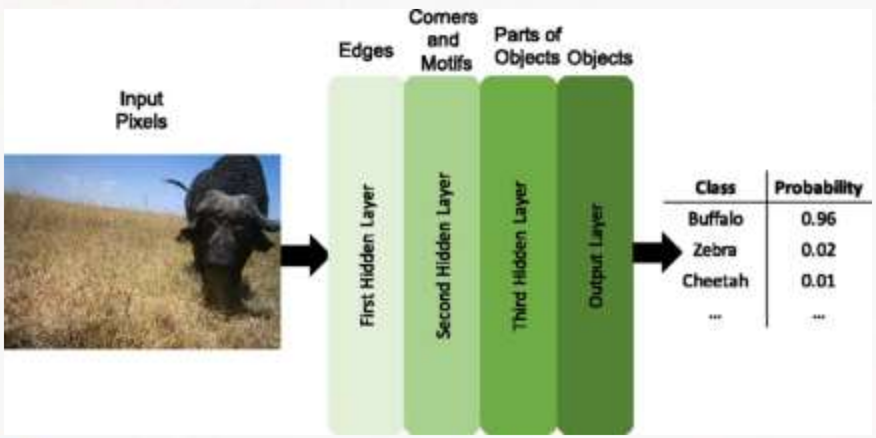
Objective

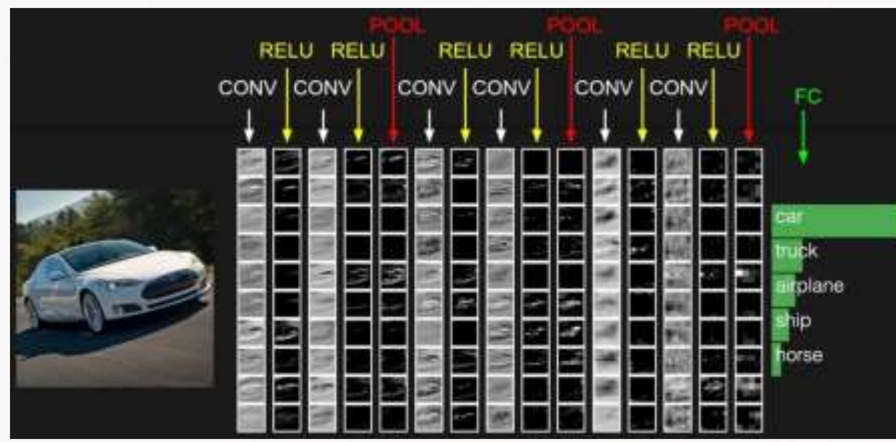
- To predict Gleason grade grouping from publicly available prostate MRIs using a **convolutional neural network** (**CNN**).
- A CNN is a **machine learning algorithm** that mimics the function of the **human visual cortex**.
- To design software that emulates the role of a fellowship-trained radiologist.



The **Big** Challenge

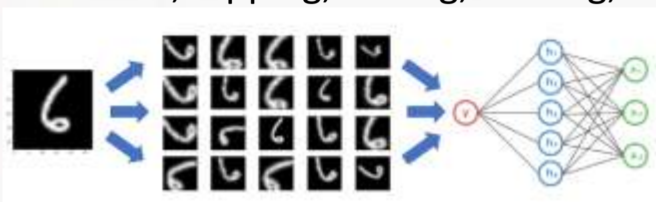
- Paucity of publicly available data:
  - Natural image datasets: 1,000,000+ images.
  - NIH dataset of CXRs: 100,000+ images.
  - **SPIE Prostate Classification Challenge**: ~200 MRIs and ~100 delineated lesions.





Solutions: Increasing the Available Data

- **Data augmentation**: Methods to **artificially** increase data size.
  - Rotation, flipping, scaling, shifting, adding noise, etc.



- **Transfer learning**: Applying solutions for one problem to a related problem.
  - Does not work well for unrelated image sets (**domain shift**).
  - Requires a **pre-trained model** (not available for prostate MRIs).

Step 1: Data Pre-Processing and Augmentation

Registration

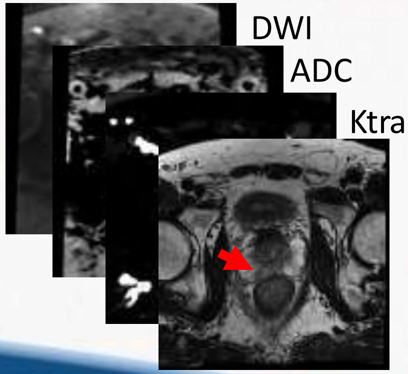
- Rigid-body alignment
- Resampling

Patch Generation

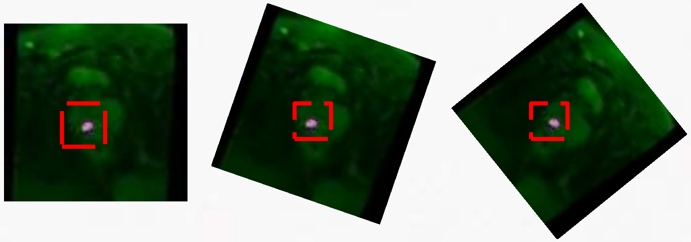
- Region localization
- Cropping the region of interest (ROI)
- Augmentation: Rotation
- Intra Image Normalization [0, 1]

Validation

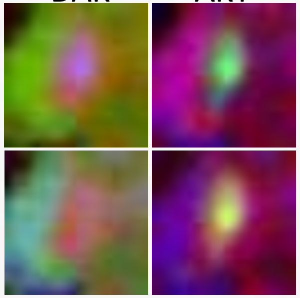
- 10-fold cross validation
- Channel composition



DWI
ADC
Ktrans
T2WI



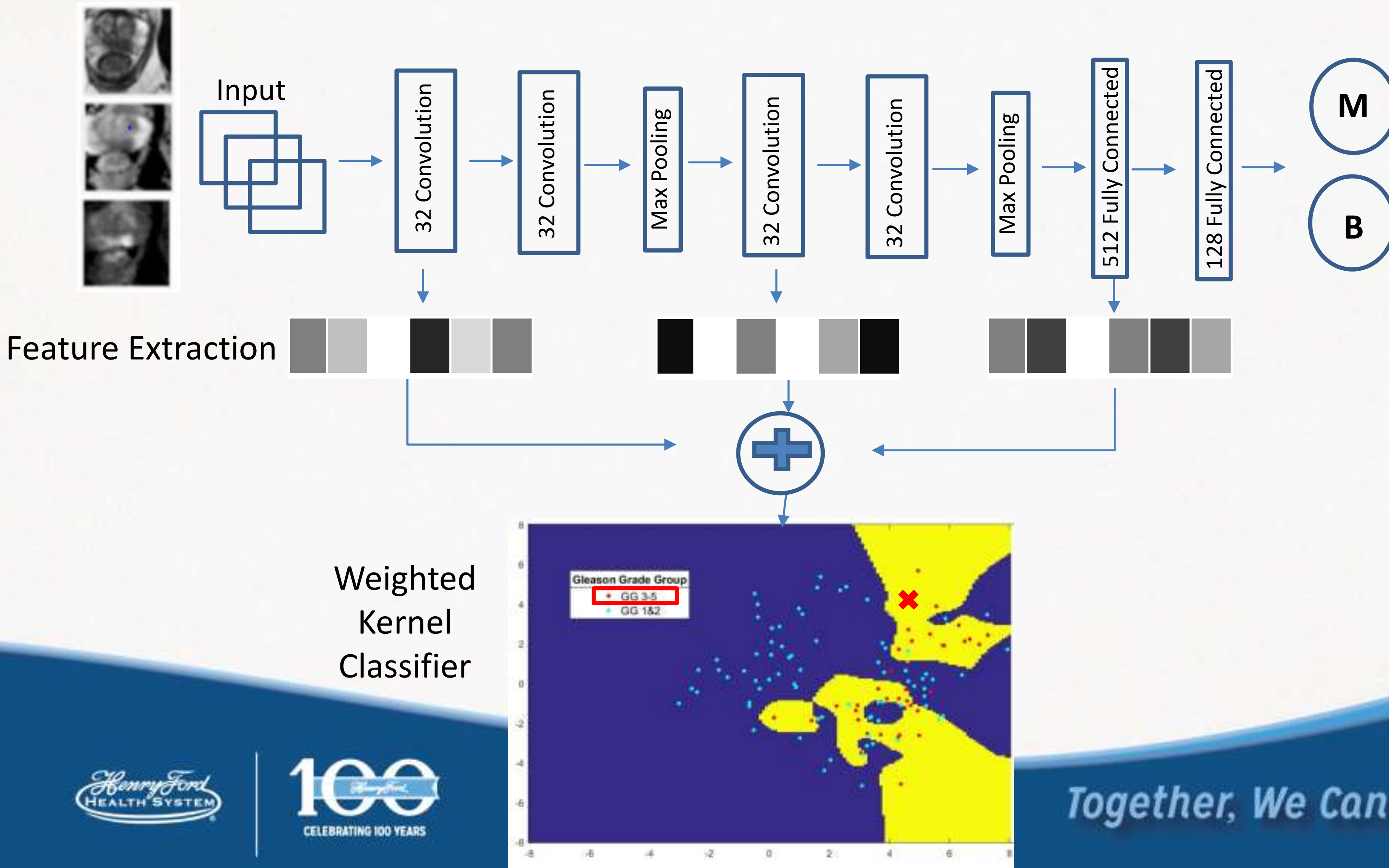
DAK AKT



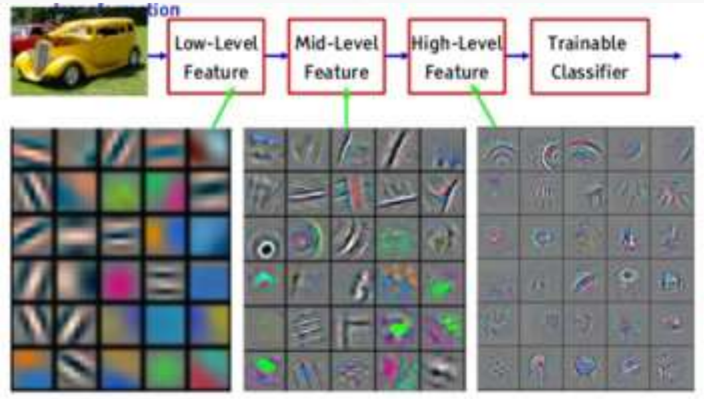
DAT DKT

DWI(D), ADC(A), Ktrans(K), T2WI (T)

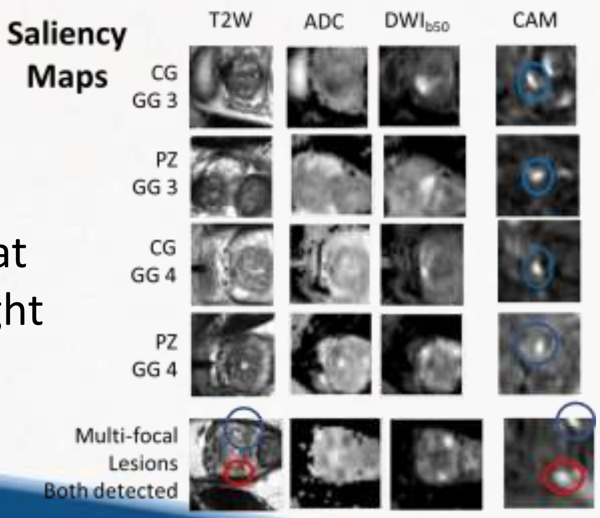
Step 2: Training
Step 3: Transfer Learning



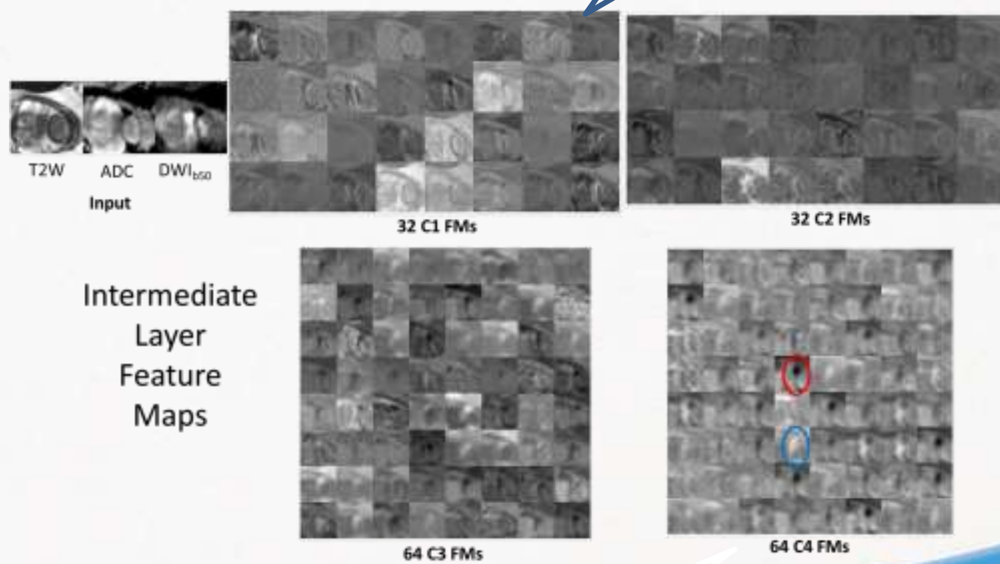
Step 4: Feature Visualization



Edge Detector



Model looks at the right place!



Intermediate Layer Feature Maps

Abnormity Detector

SOTA Results

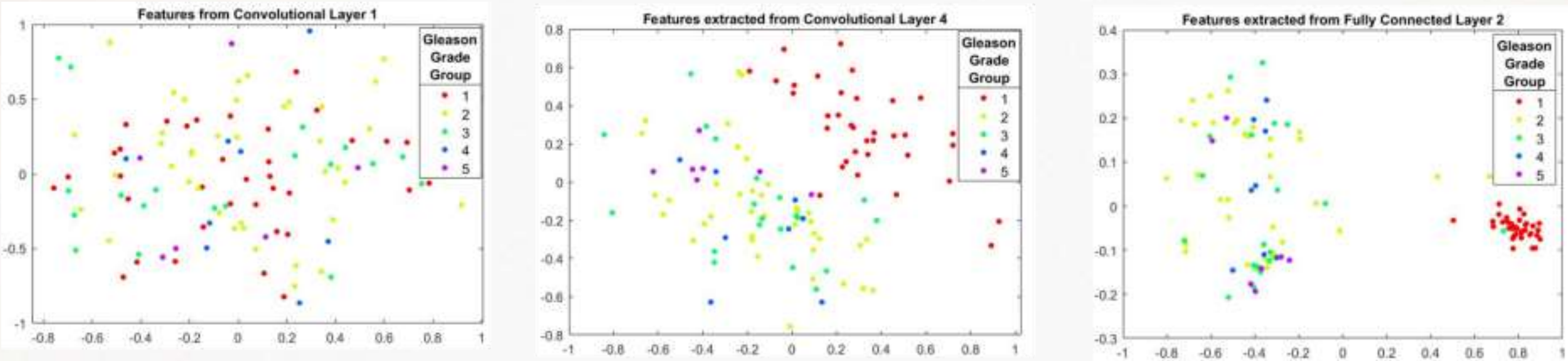


Figure: t-SNE Plot Showing Data's tendency to become more separable as Layer Propagates for Pre-trained CNN.

Table: Average cross validation results showed combining low and high level features demonstrated the best feature representation for GGG prediction task.

GG 1 vs. 23 vs. 45 3-fold CV AVG	Features From C1	Features From C4	Features From FC1	Final Result of the CNN
GG 1 Accuracy	0.41	0.95	0.97	**1.00**
GG 2&3 Accuracy	0.59	0.68	0.70	**0.68**
GG 4&5 Accuracy	0.27	0.80	0.80	**0.87**
G-mean	0.24	0.71	0.73	**0.76**

Conclusions

- Data heterogeneity and small sample size present big challenges to accurate Gleason grade prediction for prostate CA.
- We overcame these challenges and trained a convolutional neural network using data augmentation and transfer learning.
- The accuracy of our model ranged between 0.68-1.00 across different Gleason grade groups, with an overall performance of 0.76 (G-mean).

Thank You!

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