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Transformation of J-PET Raw Data into Images for Classification using Convolutional Neural Networks

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Non-image PET data

Features selected to describe each coincidence event:

1) angular difference between the detection points
2) detection times difference
3) distance between detection points
4) energy difference
5) energy sum
6) attenuation factor

Development of classification method of coincidence events is crucial since only true events are essential for PET imaging.

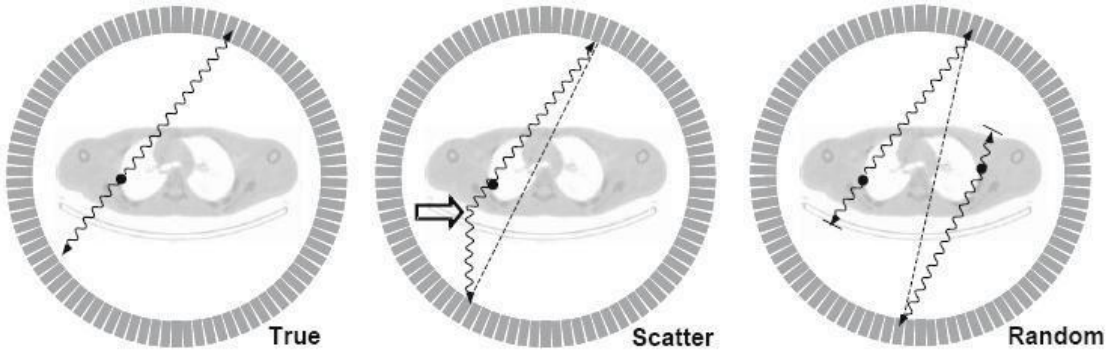


Figure: Different types of events in PET measurement. Figure adapted from [1].

[1] Jeffrey D. Steinberg, Mri-based Attenuation Correction For Pet Reconstruction, (2008).

Non-image PET data

Features selected to describe each coincidence event:

1)	angular difference between the detection points	144 deg
2)	detection times difference	0.24 ns
3)	distance between detection points	77.3 cm
4)	energy difference	35 keV
5)	energy sum	587 keV
6)	attenuation factor	0.15

How to present these numbers as an image?

Non-image data transformation

- DeepInsight approach: First transform non-image data to a well-organized image form. Then apply CNN for classification.

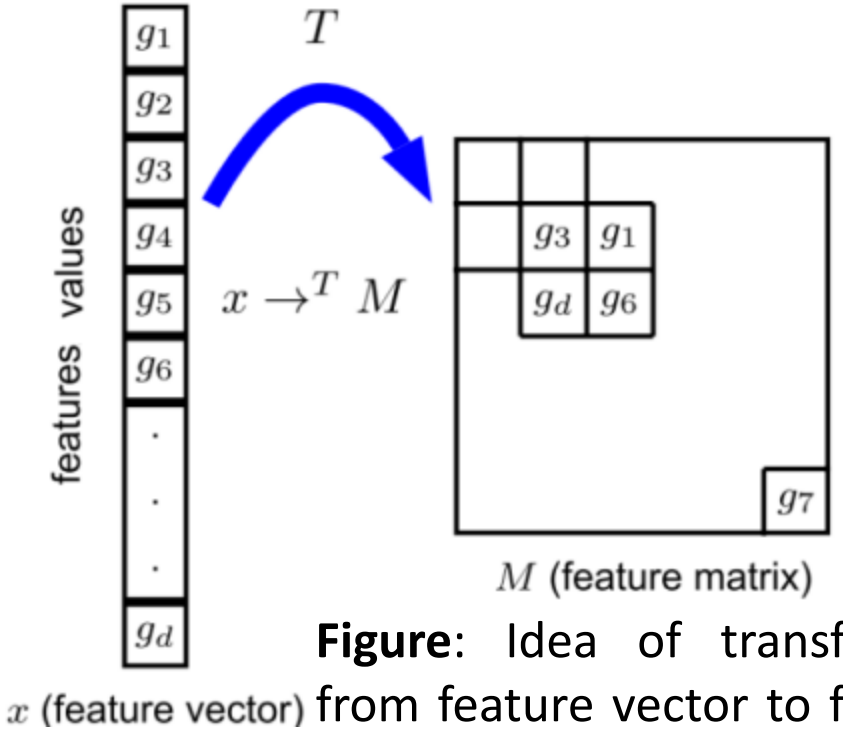


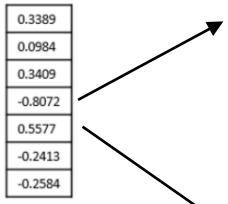
Figure: Idea of transformation (T) from feature vector to feature matrix (image-form). Figure adapted from [2].

[2] A Sharma et al. DeepInsight: A methodology to transform a non-image data to an image for convolution neural network architecture. Scientific reports, vol. 9 pp.1 (2019)

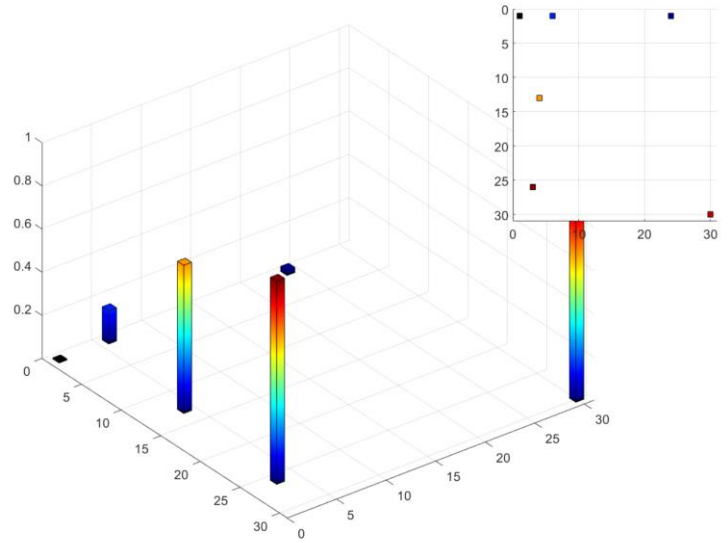
Results

DeepInsight „raw” method [2]

- perform kernel PCA to get coordinates of each feature
- final image as the rectangular convex hull
- the final image consists of as many non-zero pixels as there are features (in case of J-PET data – 6)

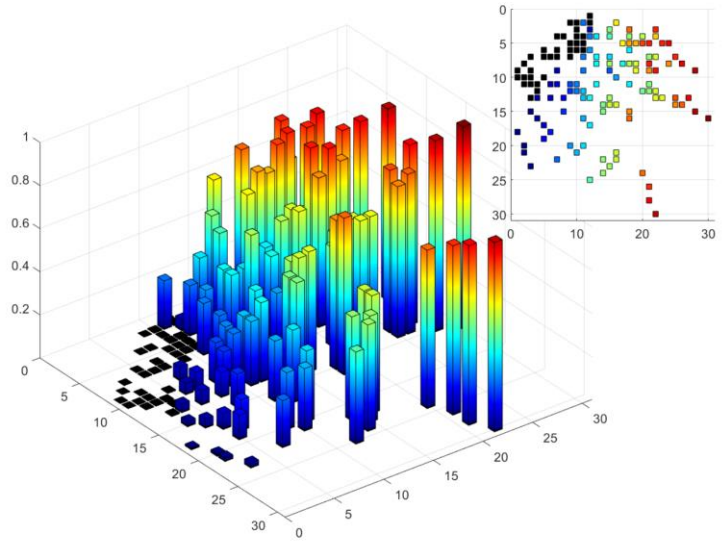


event

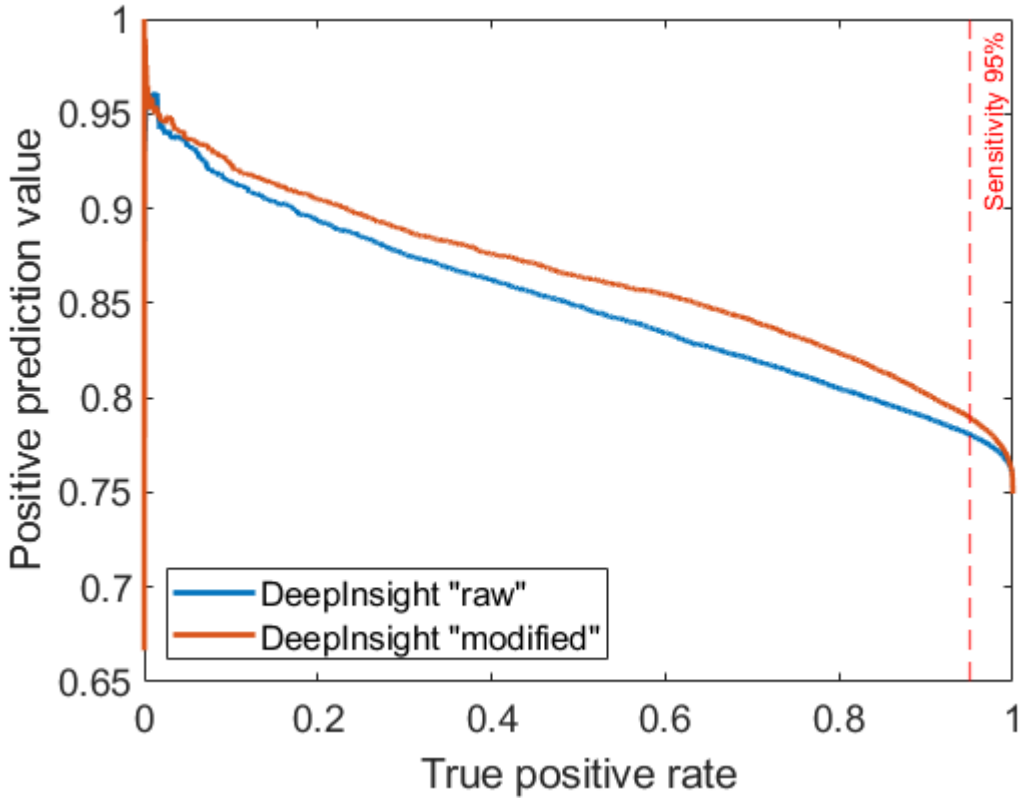


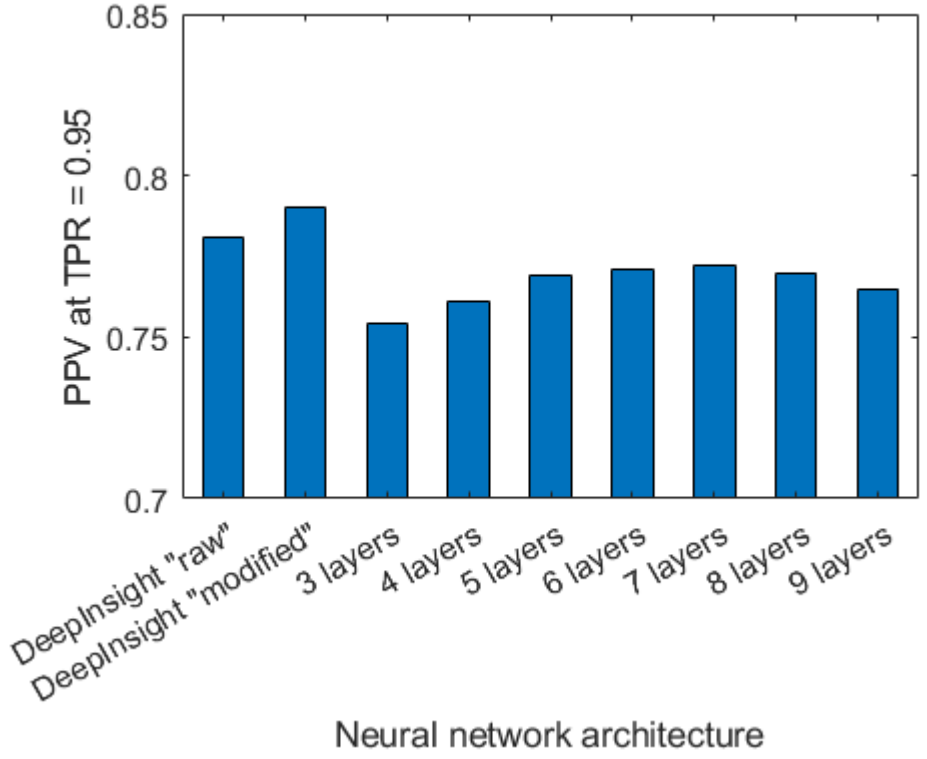
Our method (DeepInsight „modified”)

- feature engineering using kernel function
- perform PCA to get coordinates of each feature
- final image as the rectangular convex hull
- number of non-zero pixels can be manipulated (using 4th degree polynomial function gave 150 non-zero pixels)



Results


Positive prediction value
True positive rate
Sensitivity 95%
DeepInsight "raw"
DeepInsight "modified"
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0
0.2
0.4
0.6
0.8
1


PPV at TPR = 0.95
0.85
0.8
0.75
0.7
DeepInsight "raw"
DeepInsight "modified"
3 layers
4 layers
5 layers
6 layers
7 layers
8 layers
9 layers
Neural network architecture

Summary

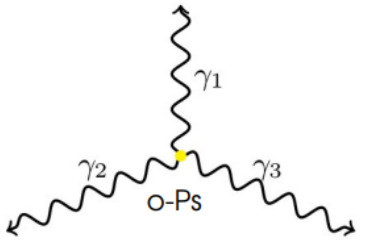
IN PROGRESS

- article comparing results of different CNN architectures using simulated data – submitted to Physica Medica EJoMP.

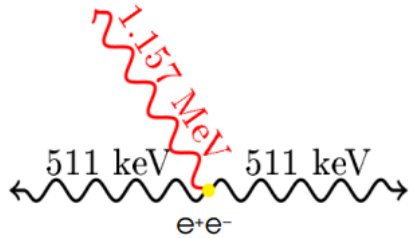
TO DO

- apply similar classification method to three-photon coincidences
- CNN model training with simulated data -> testing on real samples collected at WUM on March 2022

Ortho-positronium tomography with o-Ps→3γ decays



e+e- annihilation with additional photon from β+ emitter deexcitation



Figures adapted from [3]

[3] A Gajos. Reconstruction of three-photon events for positronium tomography and 3γ-PET technique with the J-PET scanner. Jagiellonian Symposium on Fundamental and Applied Subatomic Physics (2015).