Pattern Recognition Lab

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Automatic Dementia Screening and Scoring by Applying Deep Learning on Clock-drawing Tests[1]

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Introduction

Diagnoses in dementia are made based on paper-and-pencil tests and scored depending on personal judgments of experts. Utilizing machine/deep learning methods can counter introducing errors and help to standardize measures.

Aim: Using digitized clock-drawing tests as input for deep learning models to automatically screen and score tests for dementia diagnostics

Material and Methods

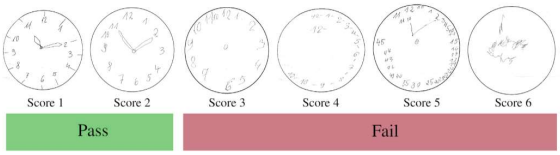

Figure 1: Clock-drawing tests (CDT) for different scores classified 'Pass' and 'Fail'.

Screening: 'Pass'		Screening: 'Fail'				
Score 1	Score 2	Score 3	Score 4	Score 5	Score 6	Total
240	351	445	152	92	35	1315

Figure 2: Subject counts for screening and scoring. The total count of subjects is 1315.

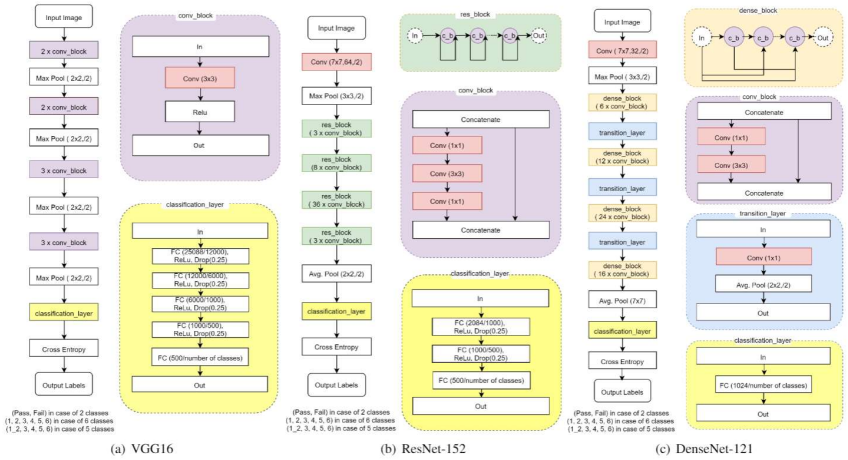

Figure 3: (a) VGG16, (b) ResNet-152, and (c) DenseNet-121 neural network architectures with modified classification layer.

- Three ImageNet pre-trained models for experiments: VGG16, ResNet-152, DenseNet-121
- Modification of classification layer (Fig.3: yellow boxes) to adapt it to use cases
- For generalization and to avoid over-fitting, validation set for training (20%)
- Manifold-learning (PCA / LLE / t-SNE) based data selection to avoid class imbalance in training
- Loss function: (weighted) cross-entropy
- Optimization
- Step learning rate scheduler for slow decay towards minimum of loss function
- 5-fold cross-validation

Results and Discussion

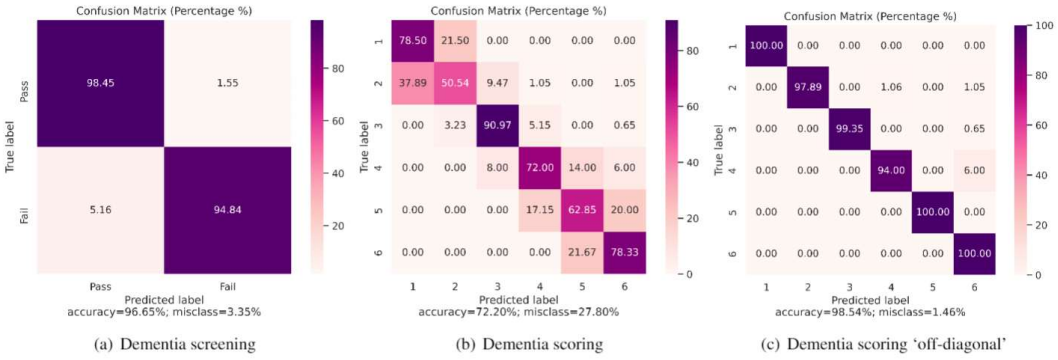

Figure 4: Average confusion matrix visualization of a 5-fold cross validation.

- Screening shows high accuracy for DenseNet-121 with LLE (Fig. 4 a) (f1=0.96, AUC=0.97)
- Screening shows high accuracy for DenseNet-121 with LLE in Fig 4. b
- Off-diagonal assumed to be a correct classification in Fig 4.c

Conclusion

We showed that deep learning can be a great tool to enable automatized screening and scoring for standardized neurological tests such as the clock-drawing test. Our proposed neural network achieved very high AUC and clearly outperformed reported clinical screening results by 24% to 27%, other machine-learning screening techniques by 4% to 24%, and machine-learning scoring approaches by 10% to 27%.

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