3D-QCNet – A pipeline for automated artifact detection in diffusion MRI images

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- Quality control (QC) is crucial for artifact detection in diffusion MRI before any analysis
- Manual QC is time-consuming and subjective
- Need for automated QC pipeline

- Goal of the paper:

Proposing an automated deep learning pipeline for artifact detection in dMRI volumes

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Using 3D-DenseNet across diverse dMRI datasets

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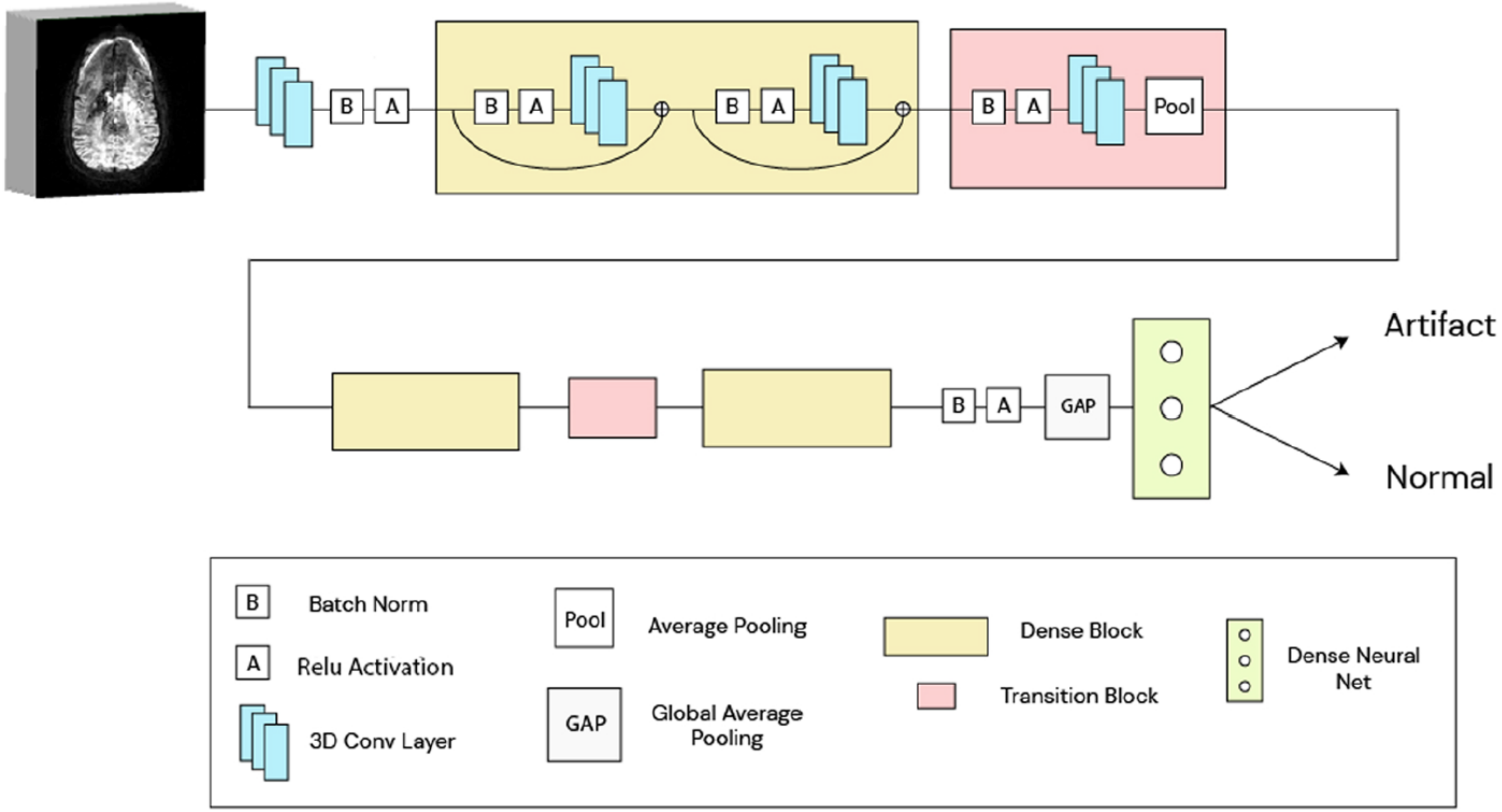
- **Model architecture**



- 3D-DenseNet with 3 dense blocks
- Transition layers for downsampling
- Global Average Pooling + softmax classifier
- Input volumes resized to 96×96×70

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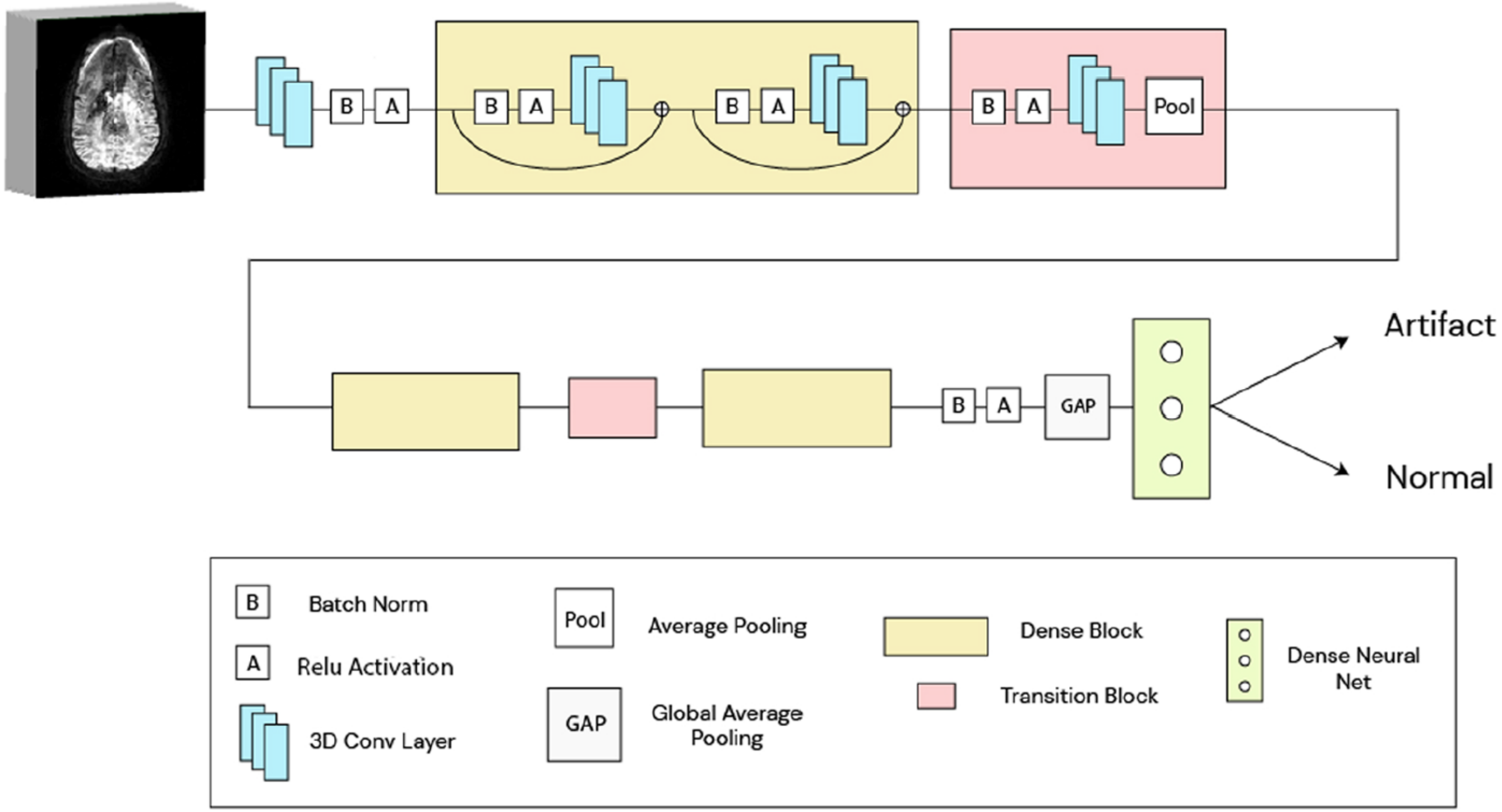
- **Training details:**



- Batch size: 5
- epochs: 20
- Optimizer: Adam
- Cross entropy loss
- Training time ~3h on NVIDIA 1080 GPU

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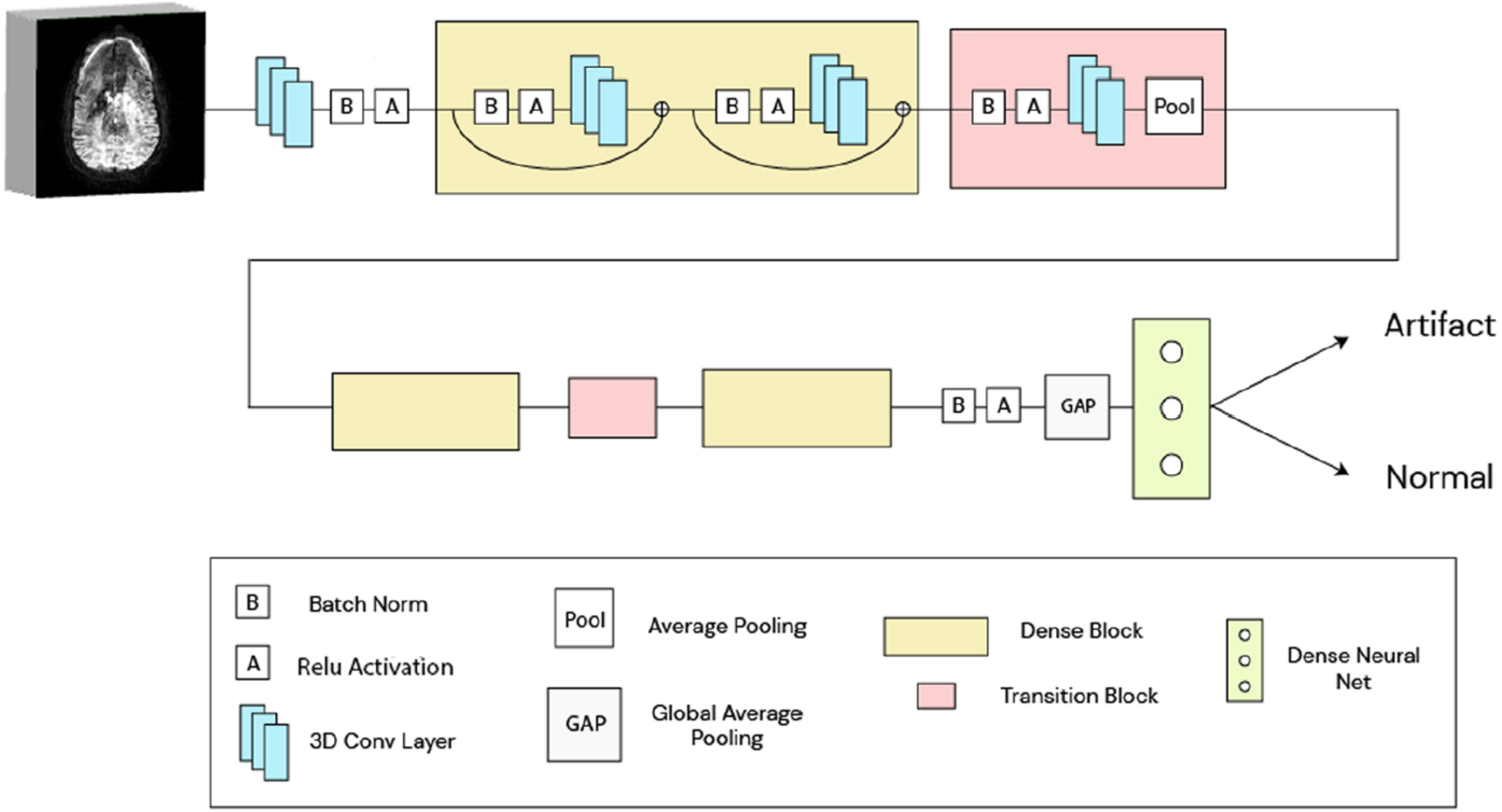
- **Inference pipeline:**



- Accepting dMRI scans, preprocessing each 3D volume to a fixed size
- Running in inference mode, providing the user with predicted artifact / normal label for each volume, calculating and reporting performance metrics
- Generating a QC report listing flagged volumes so users can drop them before further analyses

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- **Dataset**

➢ 7 datasets: 3 for training / validation, 4 for testing

➢ Total 9258 volumes from 678 subjects

- 5619 training volumes
- 1292 validation volumes
- 2347 test volumes

➢ Heterogeneous in scanners and protocols

➢ Annotating by an expert with 8 years of experience identifying artifacts in diffusion scans

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- **Results**

Results – 3D-QCNet Model.

	Dataset	Accuracy	Precision	Recall
	Dataset 1	97	95	80
	Dataset 2	81	91	66
	Dataset 3	89	90	82
Validation Set	*Average*	89	92	76
	Dataset 4	97	84	81
	Dataset 5	92	86	98
	Dataset 6	96	81	100
	Dataset 7	92	95	89
Test Set	*Average*	94	87	92

Defining “artifacts” as the positive class

✓ Consistent across 4 unseen datasets

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- **Results**

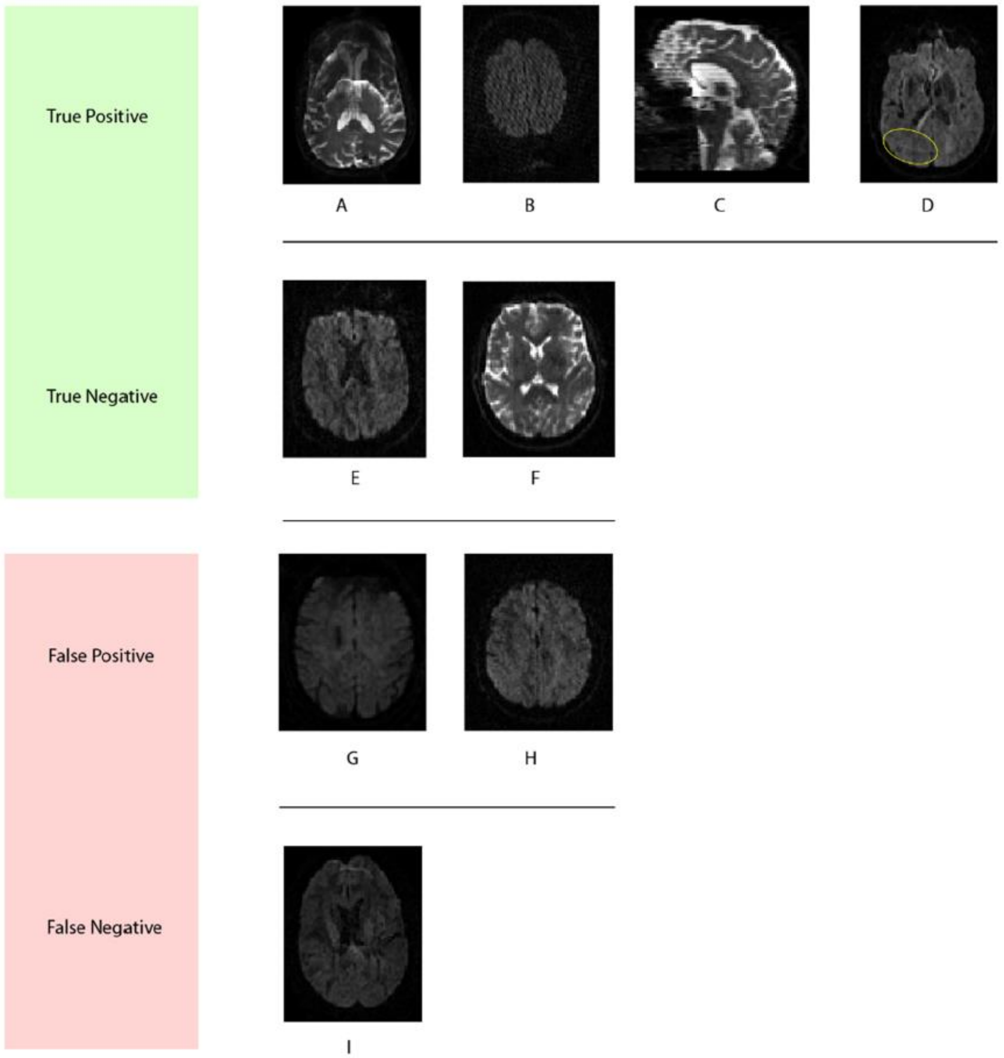

Fig. 3. Scans from the test set illustrated to demonstrate 3D-QCNet's model performance with respect to ground-truth. True Positive samples – A Ghosting artifact, B Herringbone artifact, C Motion/interslice instability artifact, D Faint Chemical artifact (marked in yellow). True Negative samples – E Weighted Image is noisy but is correctly marked as normal. F B0 image with no artifacts. False Positive samples – G Abnormal anatomy of the brain may be affecting the classifier. H Weighted image is noisy but there are no visible artifacts; the model may be too sensitive. False Negative samples – I Chemical shift artifact alongside instability and susceptibility.

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- **Results**

False Positive

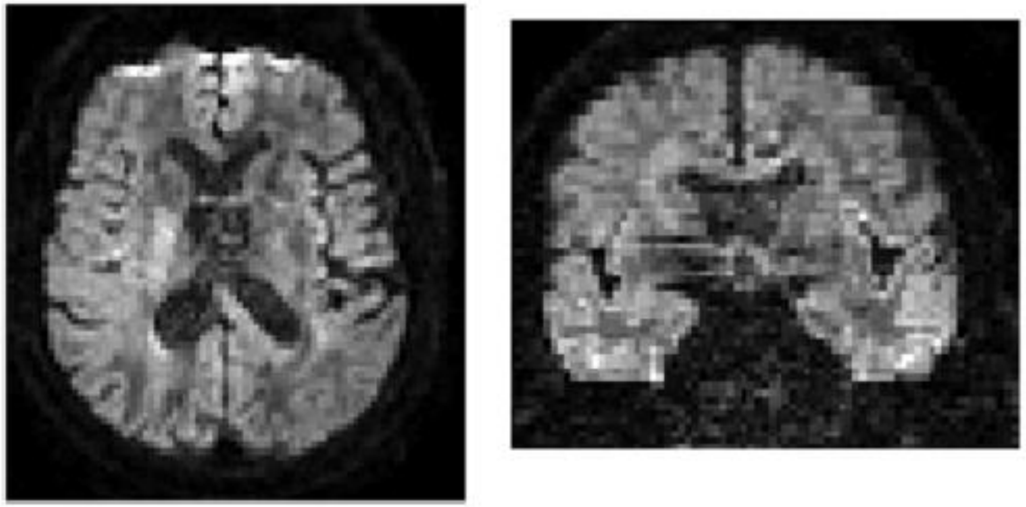

Fig. 4. These scans are from a volume that was marked as normal by our annotator but 3D-QCNet labelled it as having an artifact. Later, on closer inspection it was found to have ghosting artifacts in the ventricles and subcortical regions along with some interslice instability.

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- **Results**

Results on Dataset 5 when using labels from different annotators.

	Ground Truth	Comparison	Accuracy	Precision	Recall
8 + years of experience ⟸	Annotator 1	3D-QCNet	92.75	86.5	98.85
A month's training on identifying artifacts ⟸	Annotator 2	3D-QCNet	76	75.6	75.6

✓ The inherent inaccuracy of Annotator 2 given their relative inexperience

✓ Due to the data it was trained on, the model is more akin to Annotator 1 and learns their expertise as well as biases

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- **Conclusion**

  ✓ End-to-end automation of dMRI QC

  ✓ Robust generalization across diverse data

  × Binary output only. It flags “artifact” vs “normal” but doesn’t identify artifact type

  × Fixed input size (96×96×70)

  × Not training on data annotated by multiple experts with similar experience

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Thank you