Ventricular and total intracranial vault segmentations for brains with extensive atrophy using three-dimensional convolutional neural networks

UNIVERSITY OF TORONTO

ONTARIO NEURODEGENERATIVE DISEASE RESEARCH INITIATIVE

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BACKGROUND

- Differential rates of atrophy in the ventricles and total intracranial vault (TIV) can be used as biomarkers of cognitive decline in dementia[1]
- Existing methods to segment the regions are either time consuming, or lacking in accuracy in patients with extensive atrophy
- Convolutional neural networks (CNNs) have gained traction for brain segmentation models

PURPOSE

To develop a 3D convolutional neural network (CNN) to segment the ventricles and TIV using multi-contrast inputs across different dementing illnesses

METHODS

- A multi-contrast (T1, T2, FLAIR) and T1-based segmentation model was developed to segment both the ventricular system and the TIV
- We compare the model's performance for TIV segmentation to MONSTR[2], BET[3], and Deep Extraction[4]
- Ventricular system segmentation models were compared to Freesurfer[5]
- The influence of each sequence on the performance of the models
- The Pearson, Dice, and Jaccard coefficients were used as performance metrics
- Models were then tested on artificially generated adversarial cases including downsampling and addition of noise.

DATASET

- 673 subjects, from 2 multicentre studies
- 297 subjects with vascular cognitive impairment or Parkinson's disease (55-86 years, 72% male) from the Ontario Neurodegenerative Disease Research Institute (ONDRI)
- 376 cognitively normal individuals with carotid stenosis (age range, % male) through the Canadian Atherosclerosis Imaging Network (CAIN) study

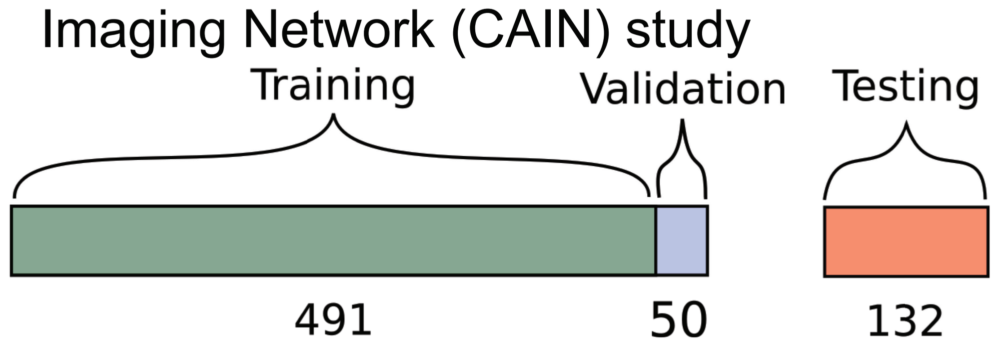

Figure 1. Distribution of subjects for model training, validation and testing

CNN MODEL

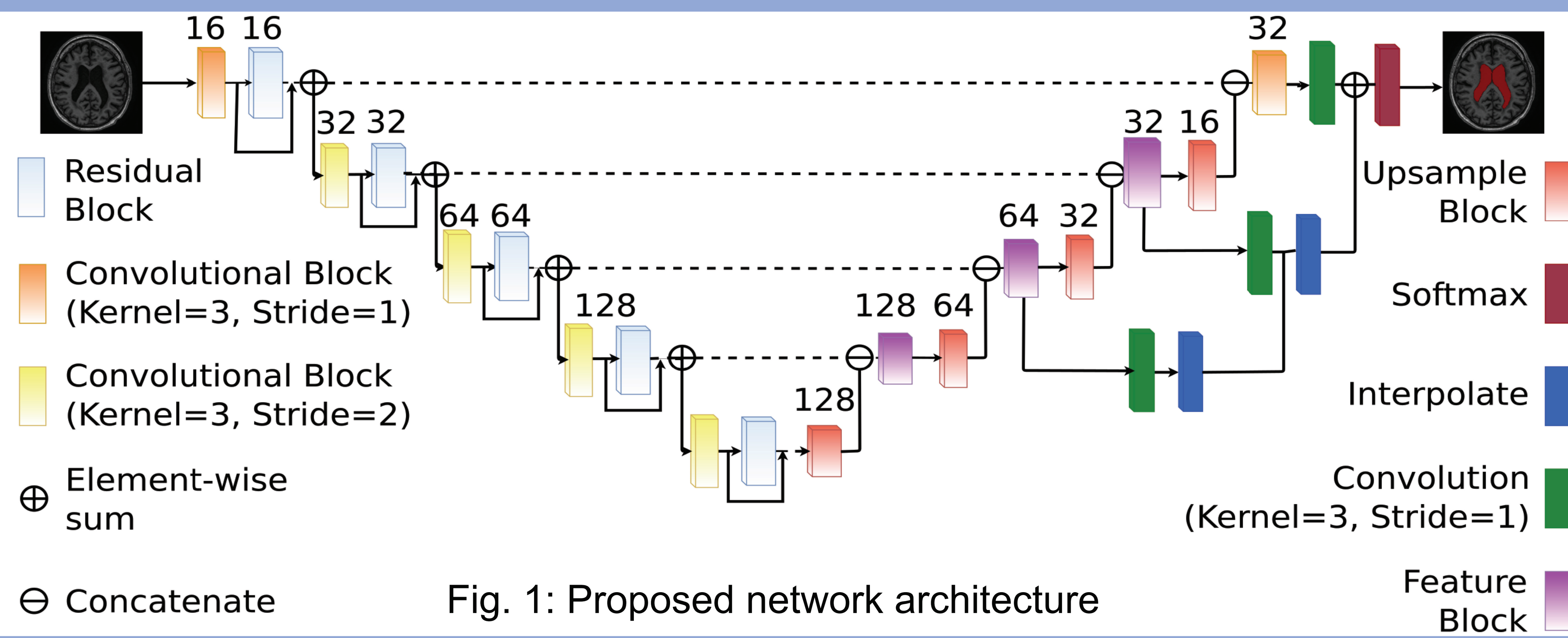

Fig. 1: Proposed network architecture

RESULTS

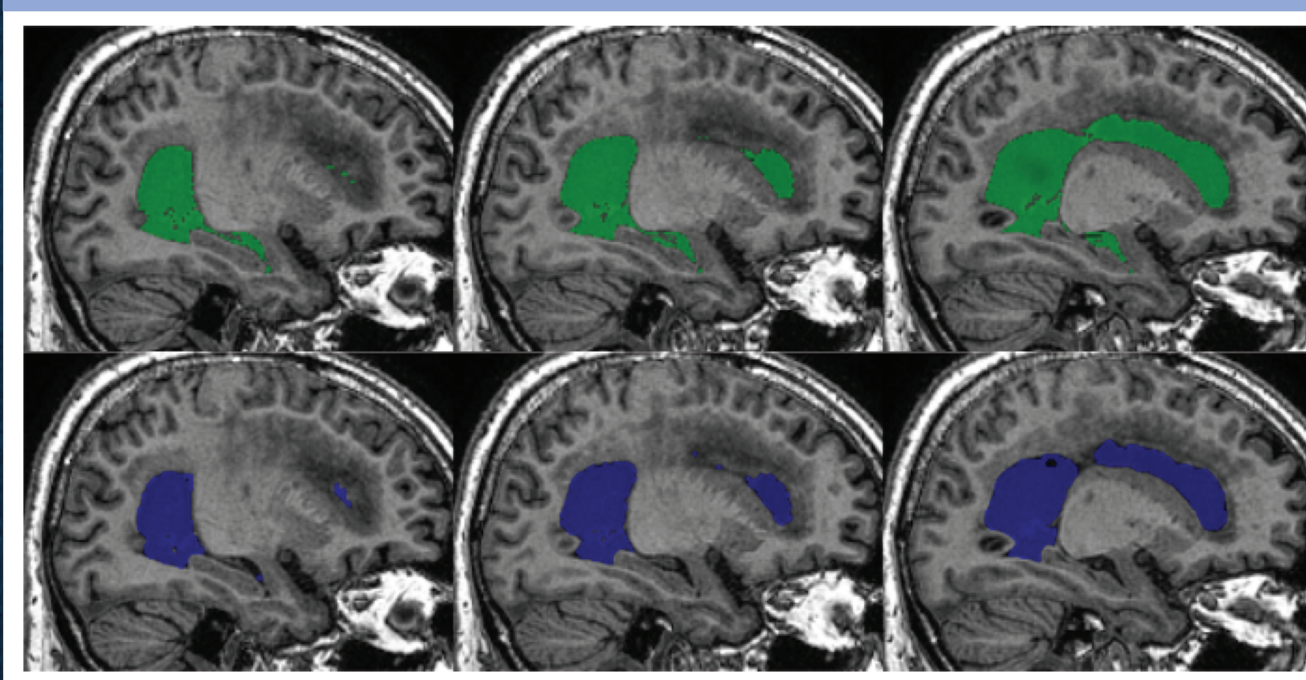

Figure 2. Ventricular segmentation results for one subject. Manual segmentations are in top row (green), U-net segmentation in bottom row (blue)

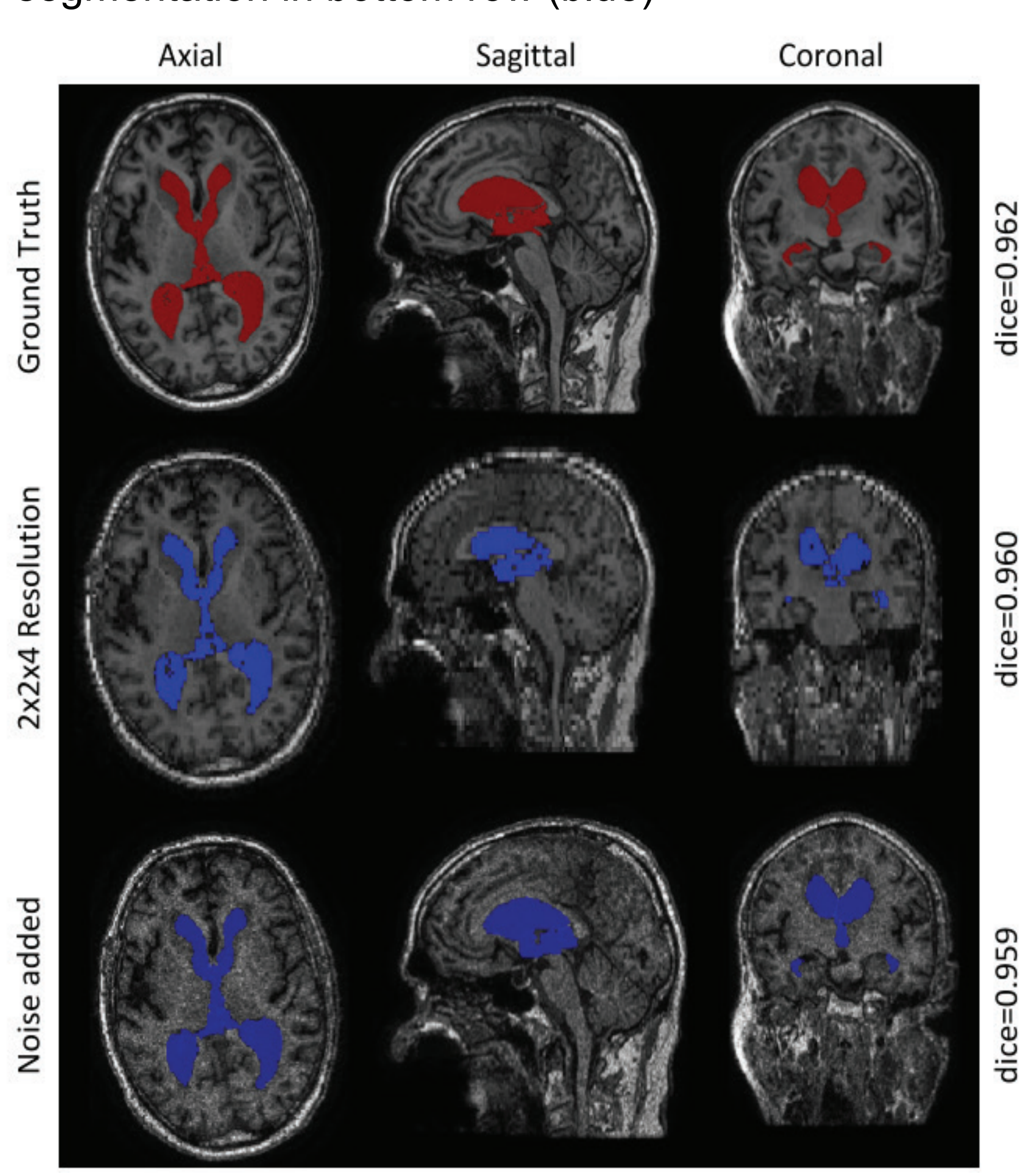

Figure 4. Ventricular segmentation results of two artificial adversarial cases applied to the same image

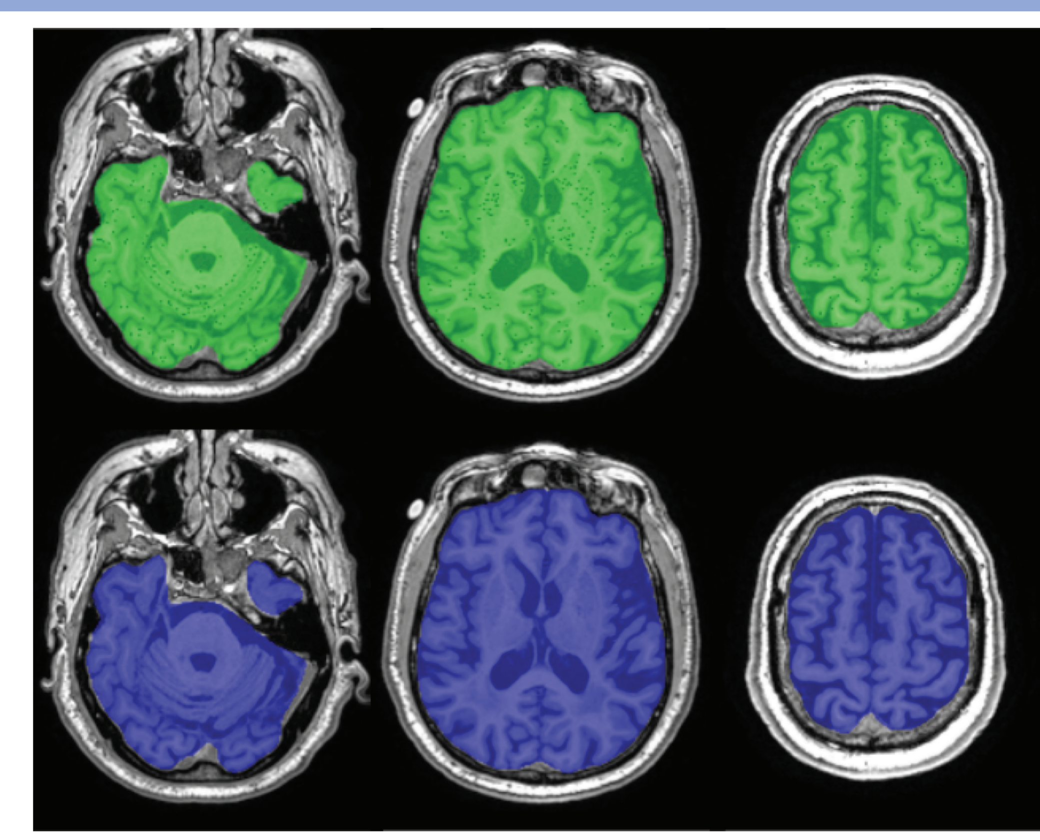

Figure 3. TIV segmentation results for one subject. Manual segmentations are in top row (green), U-net segmentation in bottom (blue)

Table 1. Dice, Jaccard, Pearson's R coefficients and computational time across ventricular segmentation methods

	Multi-contrast Network	T1-based Network	FreeSurfer
Dice	**0.924 ± 0.027**	0.896 ± 0.048	0.879 ± 0.139
Jaccard	**0.859 ± 0.044**	0.815± 0.075	0.801 ± 0.135
Pearson's R	**0.99**	0.89	0.84
Time	17 s	**11 s**	6 hours (12 cores)

Table 2. Dice, Jaccard, Pearson's R coefficients and computational time for TIV segmentation methods

	Multi-contrast Network	T1-based Network	BET	Deep Extraction	MONSTR
Dice	**0.985 ± 0.003**	0.959 ± 0.032	0.790 ± 0.166	0.863 ± 0.106	0.957 ± 0.080
Jaccard	**0.970 ± 0.006**	0.923 ± 0.057	0.679 ± 0.196	0.770 ± 0.128	0.925 ± 0.094
Pearson's R	**0.99**	0.89	0.10	0.59	0.84
Time	11 s	**9 s**	3 min	10 min	45 min

RESULTS (CONT'D)

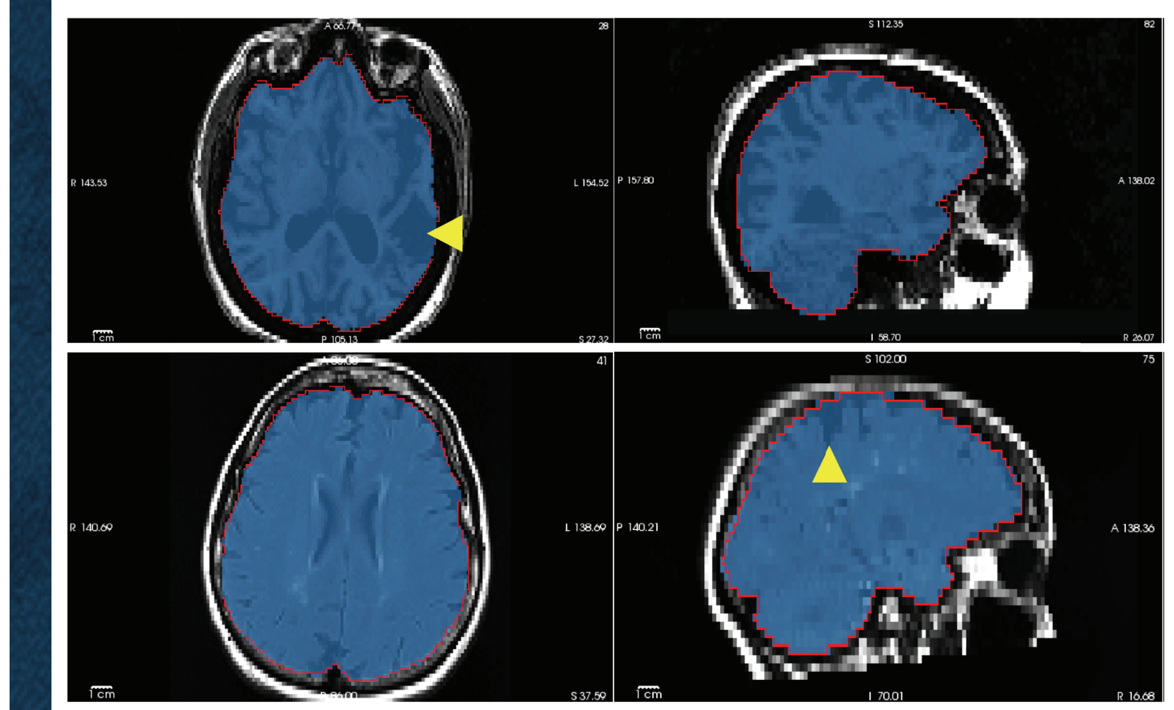

Figure 4. TIV segmentation results for two subjects who had strokes. Strokes indicated by yellow arrows. Predicted segmentation (blue label) is shown overlapping manual tracings (red outline)

DISCUSSION

- The proposed model improved on state-of-the-art methods in less time on the test dataset
- The multi-contrast, and the T1 and FLAIR based models produced the highest average dice scores for the TIV and ventricles, respectively (0.988, 0.966)
- The low processing time and accuracy highlight the potential to translate the models to large-scale studies and clinical practice
- Models seem robust to downsampling and addition of noise but cannot segmenting inputs not in standard orientation.
- Future work will investigate datasets with other disorders such as hydrocephalus, and real adversarial cases including motion.

ACKNOWLEDGEMENTS

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