TADM: Temporally-Aware Diffusion Model for Neurodegenerative Progression on Brain MRI

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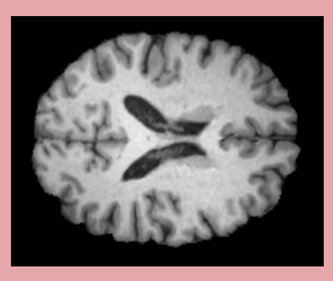
1. Brain Disease Progression Modelling

The brain progression modelling task aims at forecasting the disease evolution by predicting the brain anatomical status at an **arbitrarily future** timestamp.



Brain at age 50

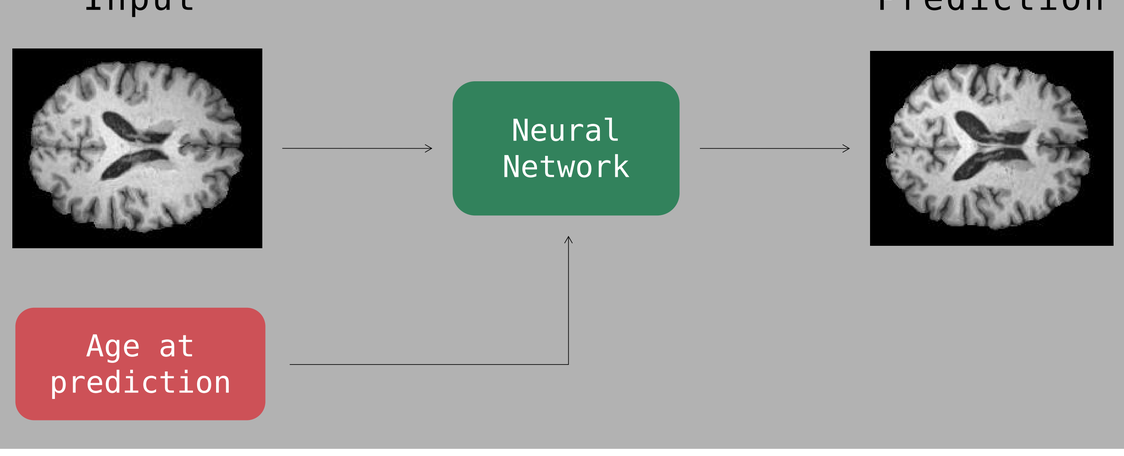
Prediction

?

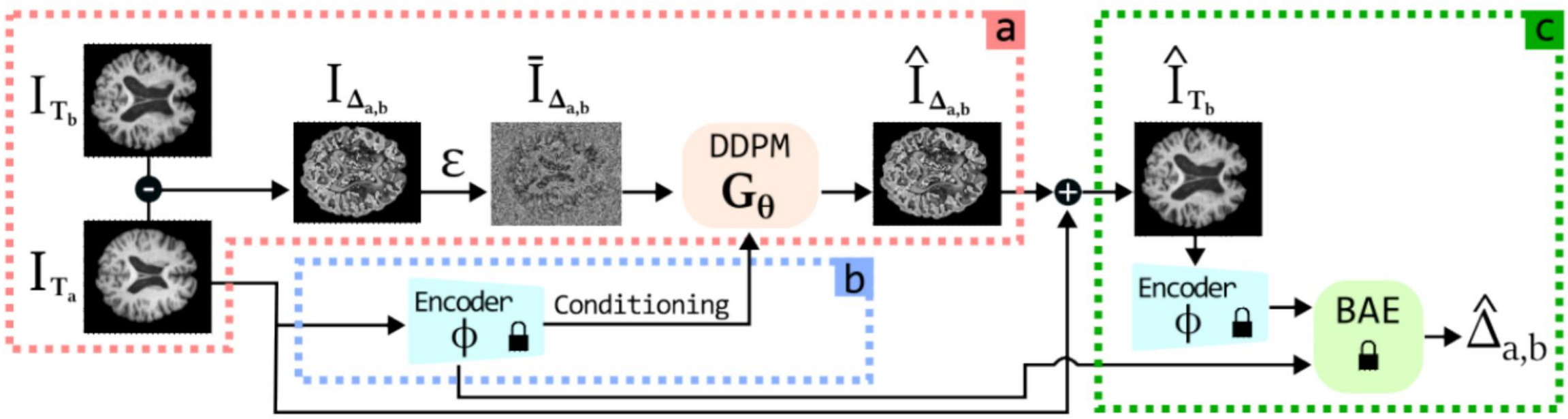
Brain at age 60

2. Previous Approaches

Previous works fail to explicitly capture the relationship between structural changes in the brain and time intervals by conditioning only on the future age.



3. Proposed Method



To accurately learns the distribution of the anotomical changes within a specified time intervals, our method:

- Learns to predict the **intensity difference** between baseline and follow-up MRIs.
- Conditions the model on the **age gap** between the input and output scans rather than directly on the output age.
- Leverages a **Brain-Age Estimator** to generate scans the accurately reflect the expected age gap.

6. Results and conclusions

Method	SSIM ↑	PSNR ↑	Region Size Error (%) ↓ Gray Matter	White Matter	Cerebrospinal Fluid	Total Brain
DiffuseMorph [7]	0.68	19.67	10.40 ± 3.45	3.49 ± 2.58	4.65 ± 2.80	46.30 ± 7.51
4D-DaniNet [14]	0.65	16.99	2.21 ± 1.08	2.57 ± 1.98	3.12 ± 3.65	9.31 ± 8.72
DDM [8]	0.69	19.59	2.44 ± 1.35	3.05 ± 2.74	4.37 ± 3.12	10.85 ± 11.64
TADM (Proposed)	**0.72**	**20.51**	**1.69 ± 1.54**	**1.85 ± 2.20**	**2.70 ± 2.29**	**6.84 ± 5.00**

Table 1. Quantitative results on image-based metrics and region size error.

Method	SSIM ↑	PSNR ↑	Region Size Error (%) ↓ Gray Matter	White Matter	Cerebrospinal Fluid	Total Brain
TADM w/o patient's data	0.71	20.32	1.78 ± 1.44	1.97 ± 2.14	2.72 ± 1.98	7.85 ± 5.17
TADM w/o BAE	0.69	20.08	2.44 ± 2.12	2.02 ± 2.13	3.85 ± 3.67	9.77 ± 8.23
TADM w/ age cond.	0.68	19.71	4.12 ± 3.48	4.98 ± 2.45	5.65 ± 3.32	11.95 ± 7.34
TADM	**0.72**	**20.51**	**1.69 ± 1.54**	**1.85 ± 2.20**	**2.70 ± 2.29**	**6.84 ± 5.00**

Table 2. Ablation study of TADM components.

Figure 2. Qualitative results at different age gaps.

In this paper, we propose TADM, a novel approach designed to accurately mimic brain neurodegenerative progression in MRIs, by focusing on learning the anatomical changes of the brain within a time interval.

Paper and code

https://github.com/MattiaLitrico/TADM-Temporally-Aware-Diffusion-Model-for-Neurodegenerative-Progression-on-Brain-MRI

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