RS-Net: Regression-Segmentation 3D CNN for Synthesis of Full Resolution Missing Brain MRI in the Presence of Tumour

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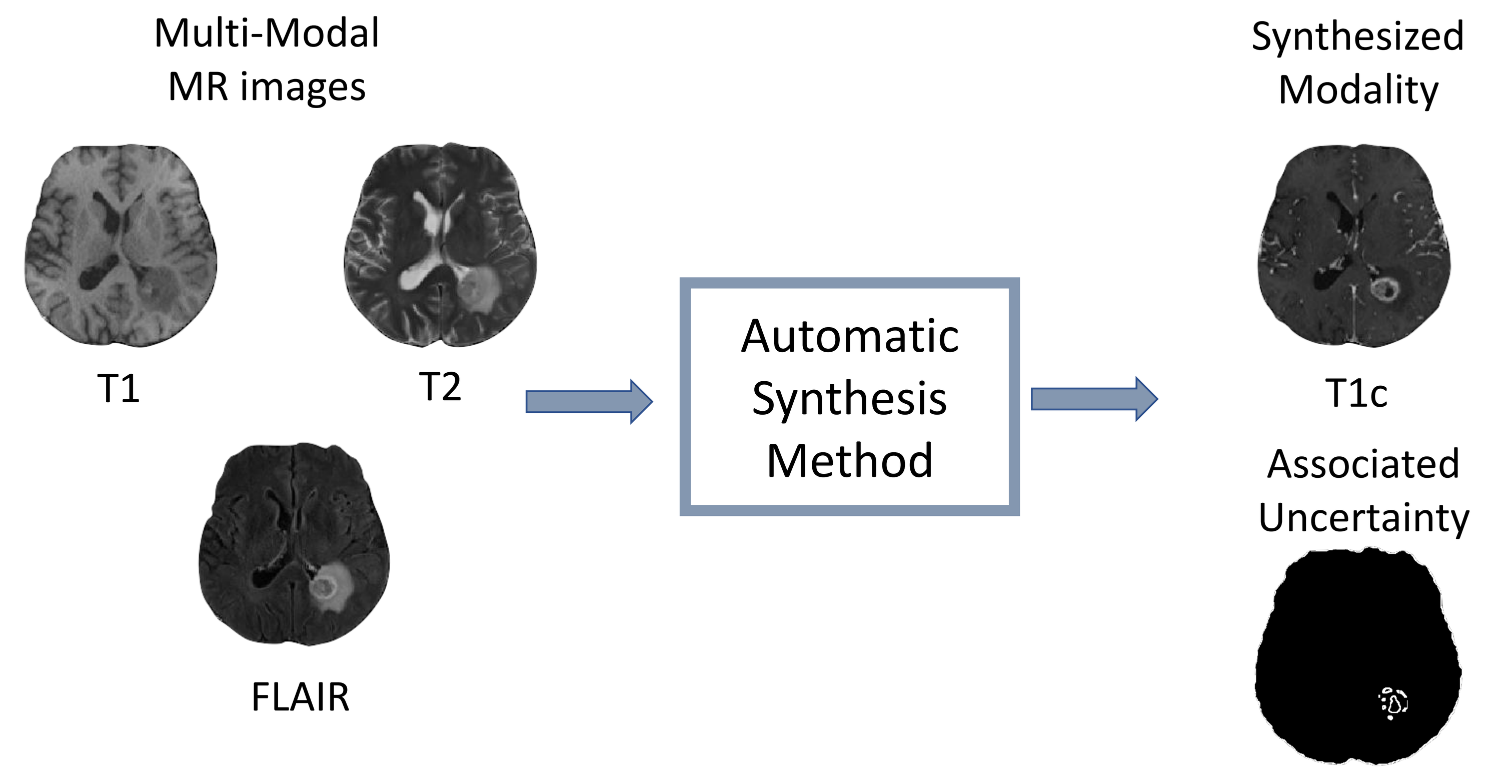
(1) Introduction

- Multi-modal magnetic resonance images (MRI) improves analysis of neurological diseases such as brain tumours.
- Not all required MRI sequences will be reliably available in real clinical contexts due to:
  - Cost or time constraints
  - Corruption due to noise
  - Patient motion, etc.
- Automatic synthesis of MRI sequence from available sequences would be very helpful – **particularly in area of the tumour**.
- In order to use them reliably, should quantify confidence in the synthesized MRI.

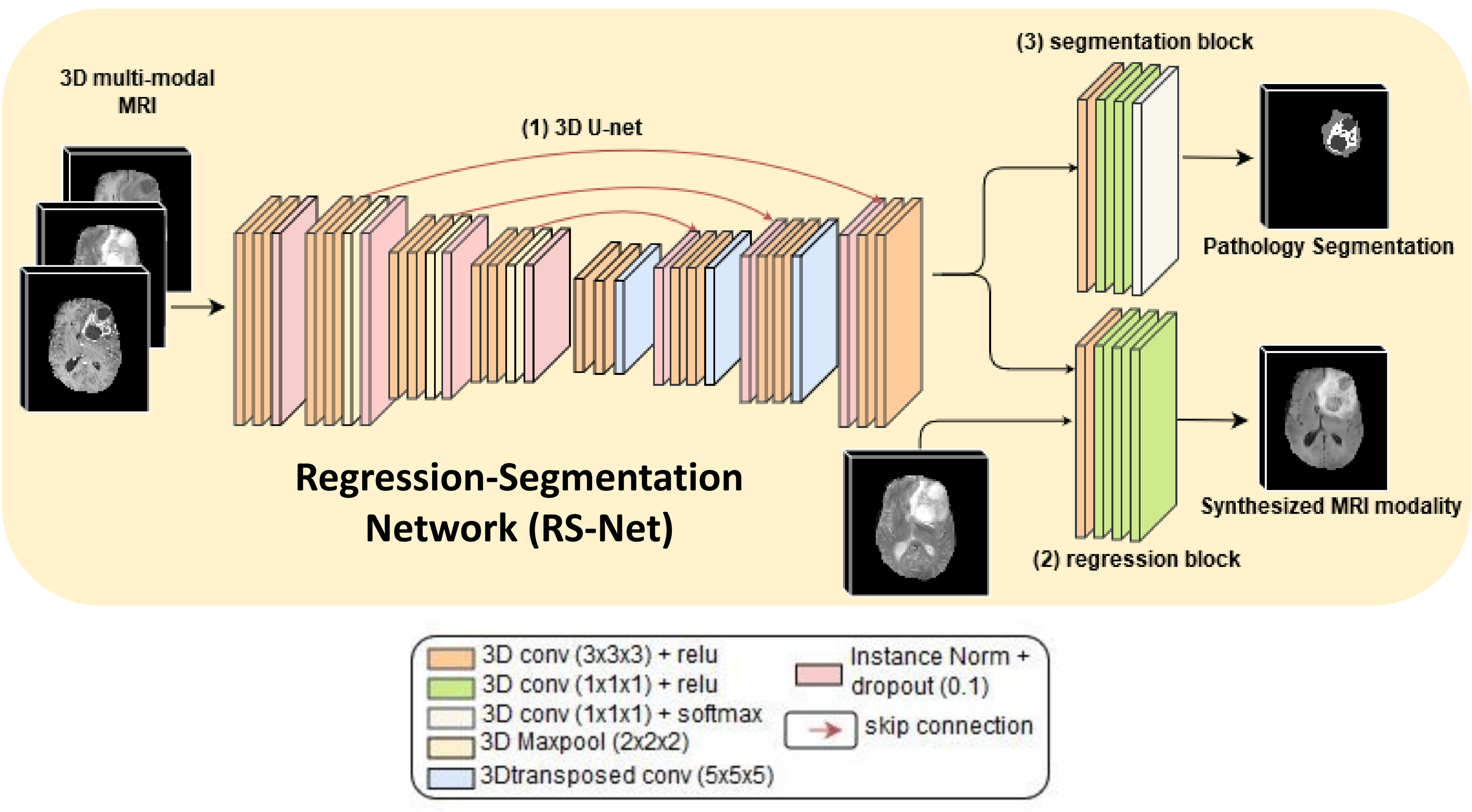
(2) Objective of the Work



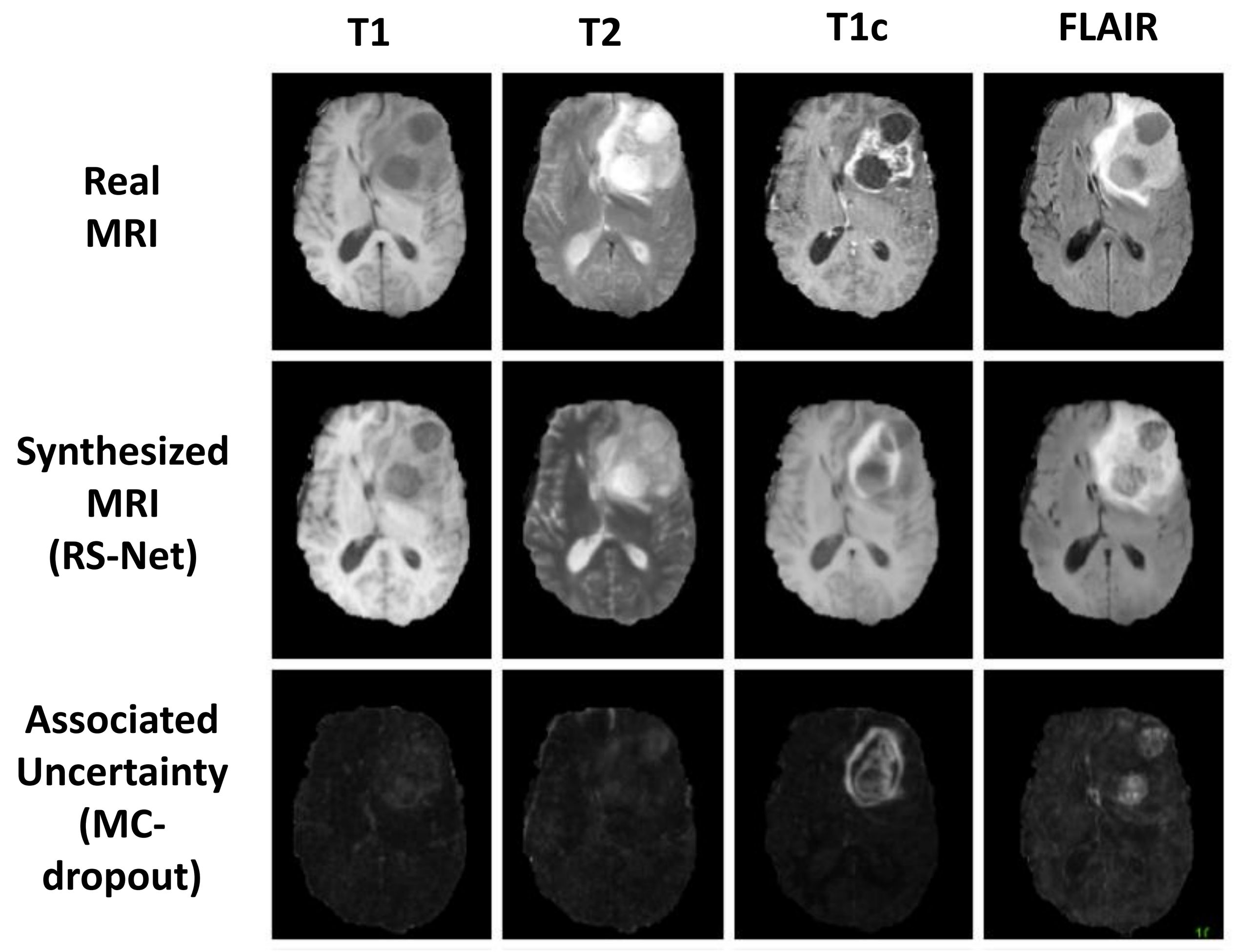
(3) Dataset and Pre-Processing

- BraTS 2017 Dataset
  - Training Set: 210 HGG and 75 LGG patients
  - Validation Set: 46 patients
- BraTS Training set: train (228) and validate (57) network.
- BraTS Validation set: test network
- BraTS challenge provides isotropic, skull-stripped, and co-registered MR volumes (T1, T2, FLAIR, T1c)
- Manual labels for tumour sub-types: Edema, Necrotic core, and Enhancing Tumour.
- Pre-processing: Intensity Standardization using the mean and standard deviation over the masked region of a given MR image

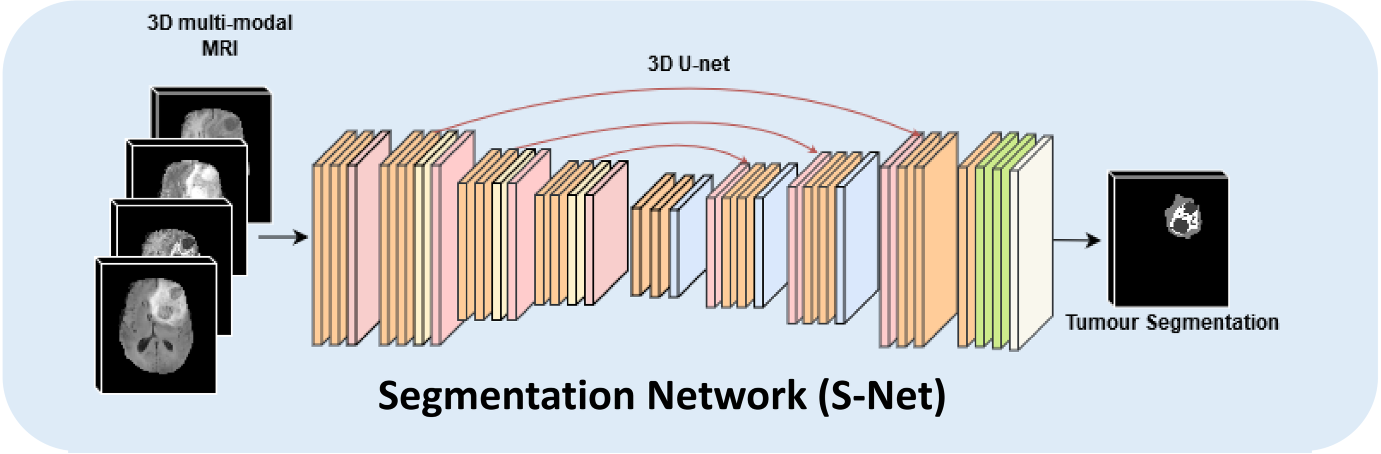
(4) Proposed Method



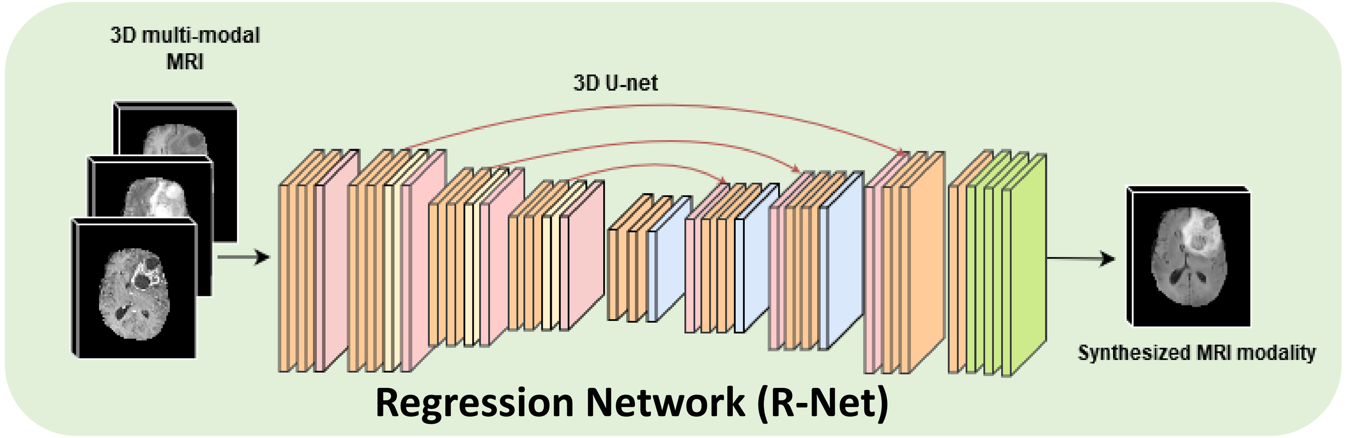
(5) Qualitative Results



(6) Evaluation Network



(7)Baseline Network for Comparison



(8) Quantitative Results

- Synthesis quality based on downstream tumour segmentation task.
- Trained a segmentation network (S-Net) on Real MR Images; Replace real with synthesized (RS-Net, R-Net);
- **Objective: Minimal loss in segmentation accuracy when real image replaced with synthesized image**

	T1	T2	FLAIR	T1c	Dice Enhance	Dice Tumour	Dice Core
Real	✓	✓	✓	✓	68.2	87.9	75.7
T1 Synthesis	●	✓	✓	✓	67.6	87.9	75.5
	⦿	✓	✓	✓	67.5	87.8	75.3
T2 Synthesis	✓	●	✓	✓	66.3	87.3	75.6
	✓	⦿	✓	✓	66.1	87.2	75.4
FLAIR Synthesis	✓	✓	●	✓	66.8	83.6	73.1
	✓	✓	⦿	✓	62.9	81.3	71.5
T1c Synthesis	✓	✓	✓	●	24.8	87.3	54.0
	✓	✓	✓	⦿	24.1	85.9	53.9

Multi-class brain tumor segmentation results on the BraTS 2017 Validation Dataset. Notation: Real MRI (✓), synthesized MRI RS-Net (●), and synthesized MRI R-Net (⦿). Quantitative segmentation results based on Dice coefficients for: enhancing tumor, whole tumor, and tumor core.

(9) Conclusion

- A full resolution 3D end-to-end CNN was developed for the task of MR volume synthesis in the presence of brain tumours
- **Multi-task learning (synthesis and segmentation) helps** in improving quality of synthesised MRIs
- **Real MRIs can be replaced** with synthesized T1, T2, and FLAIR volumes **with minimum degradation in segmentation accuracy**
- **Synthesizing T1ce is** still **too challenging** problem
- **Uncertainty measure** based on Monte Carlo dropout is **helpful** in communicating the confidence in the synthesis results

Reference:
[1] Cicek et al. "3D U-Net: learning dense volumetric segmentation from sparse annotation." In MICCAI, pp. 424-432. Springer, Cham, 2016.
[2] Menze et al. "The multimodal brain tumor image segmentation benchmark (BRATS)." IEEE TMI 34, no. 10 (2015): 1993.
[3] Gal and Ghahramani, "Dropout as a Bayesian approximation: Representing model uncertainty in deep learning." In ICML, pp. 1050-1059, 2016.

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