CT Synthesis with Modality-, Anatomy-, and Site-Specific Inference

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BACKGROUND

- Computed tomography (**CT**) has traditionally been the primary imaging modality in radiotherapy (RT) due to its ability to provide accurate and high-resolution patient geometry, facilitating direct electron density conversion essential for dose calculations.
- Magnetic resonance imaging (**MRI**) has proved its added value for tumors and organs-at-risk delineation thanks to its superb soft-tissue contrast. Also, cone-beam computed tomography (**CBCT**) plays a vital role in image-guided adaptive radiation therapy (IGART) for photon and proton therapy. However, they are both unsuitable for accurate dose calculations.
- In recent years, the **generation of synthetic CT (sCT) from MRI or CBCT** has increased interest based on artificial intelligence algorithms such as machine learning or deep learning. SynthRAD challenge aims to provide the first platform offering public data evaluation metrics to compare the latest developments in sCT generation methods. Our goal is to develop a unified solution to synthesizing CT from different input modalities (MRI and CBCT), anatomy regions (brain and pelvis), and imaging sites.

METHOD AND DATASET

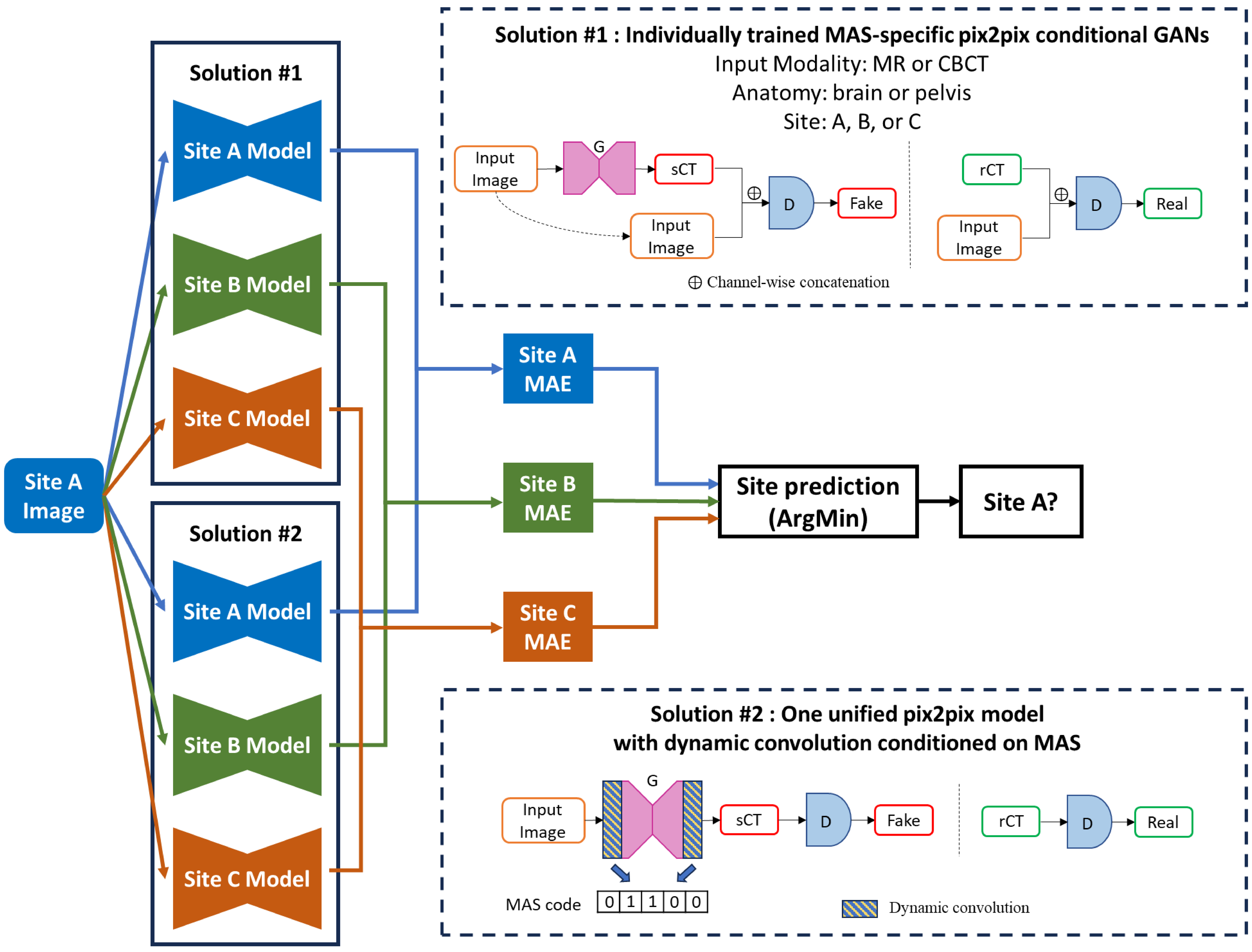

Fig. 1 An illustration of the site-prediction algorithm. We use an input image from site A as an example.

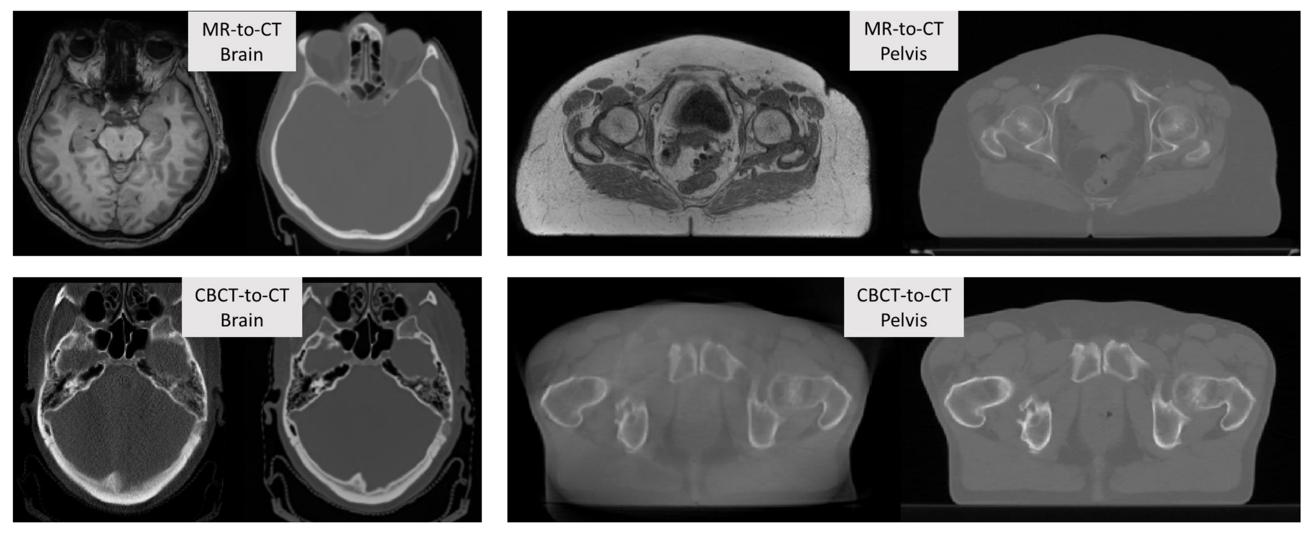

Fig. 2 Representative images for all tasks and anatomical regions.

Table 1 Training set details.

Anatomy	Brain			
Site	A	B	C	Total
Task 1: MR-to-CT	60	60	60	180
Task 2: CBCT-to-CT	60	60	60	180
Anatomy	Pelvis			
Site	A	B	C	Total
Task 1: MR-to-CT	120	0	60	180
Task 2: CBCT-to-CT	60	60	60	180
Total				720

- We design our algorithms to be modality/anatomy/site (**MAS**)-specific to avoid the potential issue of domain shift. The framework contains two MAS-specific solutions and a site-prediction algorithm to predict the imaging site.
- **MAS-specific solution #1**: Individually trained 3D pix2pix [1] models per MAS (11 models in total).
- **MAS-specific solution #2**: One unified 3D pix2pix model with dynamic convolution [2] conditioned on MAS code. The parameters of the first two and last two convolutional layers of the generator are dynamically generated using the input MAS code.
- **Site-prediction algorithm**: Since we are only provided with the modality and anatomy region information, our MAS-specific solutions #1 and #2 cannot work optimally without the correct site information. We thus design a simple uncertainty-based algorithm to predict the site of the input image. We assume that an image (e.g., from site A) is out-of-distribution data for the models that are trained/designed exclusively for site B or site C, thus the uncertainty of model from site B or site C will be higher than the uncertainty of the model from site A. We measure the uncertainty by calculating the mean absolute error (MAE) between the MAS-specific solutions #1 and #2.
- **Final output**: Ensemble of the two MAS-specific solutions using the modality (provided), anatomy region (provided) and site (predicted) information.

CONCLUSIONS

- In this SynthRAD challenge, we propose two MAS-specific solutions and a site-prediction algorithm to synthesize CT from multi-site MR and CBCT images for the brain and pelvis regions. Our framework achieves competitive results, ranking among the top 10 in both Task 1 (MR-to-CT) and Task 2 (CBCT-to-CT).

Reference:
[1] Isola, P., Zhu, J.-Y., Zhou, T., Efros, A.A.: Image-To-Image Translation With Conditional Adversarial Networks. Presented at the Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition (2017).
[2] Jia, Xu, Bert De Brabandere, Tinne Tuytelaars, and Luc V. Gool. "Dynamic filter networks." Advances in neural information processing systems 29 (2016).
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