Fachhochschule Nordwestschweiz
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Investigation of different quality assessment procedures for fast and reliable validation of CBCT-based synthetic CTs

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Bachelor's Thesis, Major Medical Informatics

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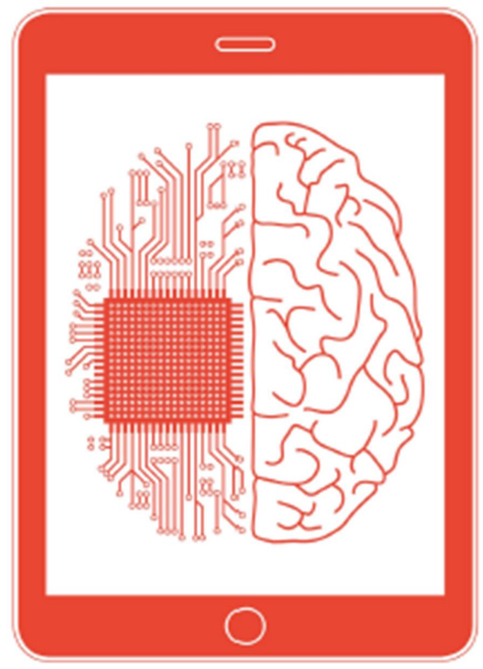

Introduction:

In Adaptive Proton Therapy (APT) a treatment plan is adjusted before each dose delivery.
↓
For dose recalculation, new image of patient's anatomy is required.
↓
For frequent imaging, diagnostic CT scans are sub-optimal due to limited accessibility during treatment [1]

Synthetic CT (sCT) images are artificially generated CT images that integrate images from two different modalities into a single composite image.
↓
CBCT-based sCTs are a promising imaging alternative for OAPT due to in-room CBCT machines being commonly integrated into the treatment room [2].
↓
There is no streamlined quality control for the CBCT-based sCTs.

Objectives:

Propose similarity measures which are able…

…to **detect** and **visualise**…

…clinically relevant **structural differences** between CBCT-based sCTs and the corresponding CBCTs.

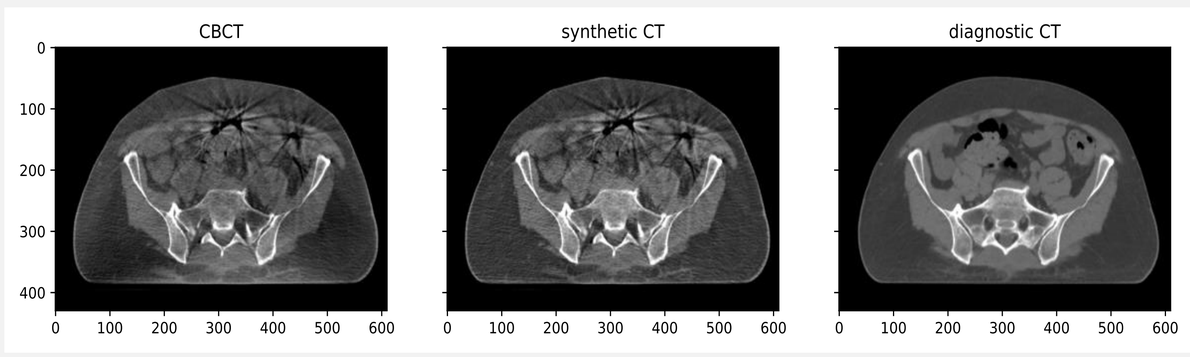

Figure 1: Comparison of a pelvic slice in three CT modalities: Left: CBCT, Middle: CBCT-based sCT, Right: diagnostic CT.

Methodology:

Measures (SSIM[1], DTW[2]) were implemented into a window sliding algorithm to compare the CBCT and corresponding sCT slices:

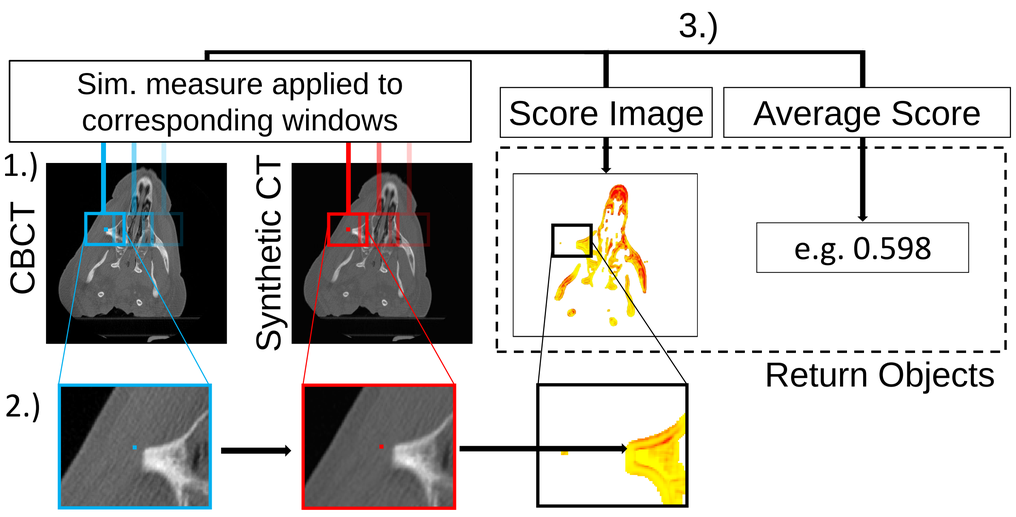

Figure 2: Outline of window siding algorithm, using the example of the Pig's Head CT scan: 1.) Extraction of windows from CBCT and sCT slices, 2.) Storing scores in the score image, 3.) Calculation of return objects.
The score image visualises the differences detected (Red: Low similarity, Yellow: High similarity).

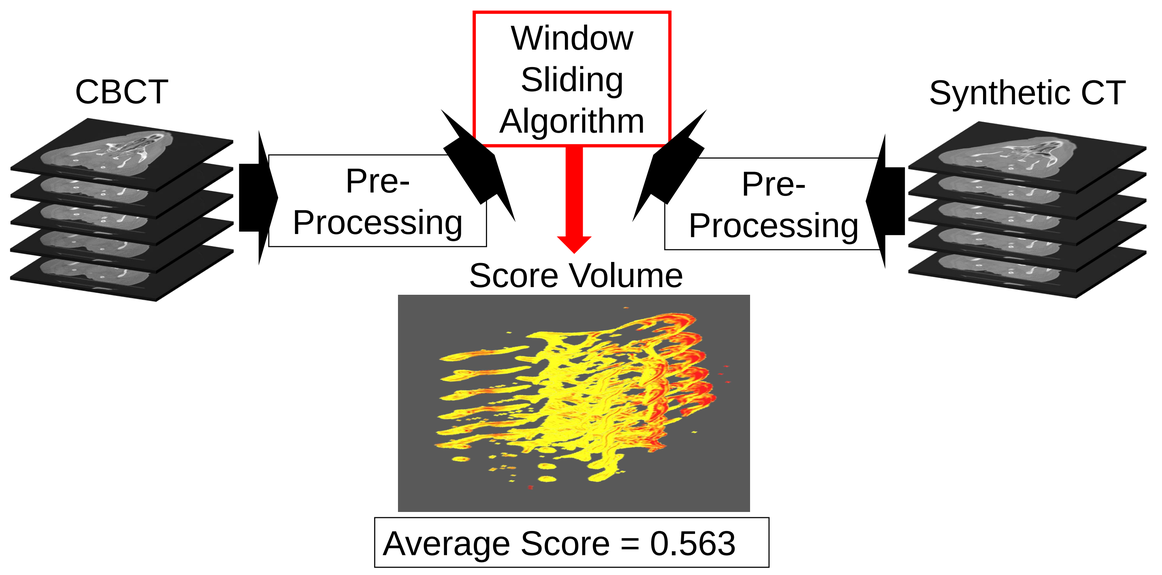

Figure 3: Outline of the process of comparing whole CT sets. After applying the window sliding algorithm to each slice, the score volume and average of all slices is returned. Gray background added to score volume for improved contrast.

Results:

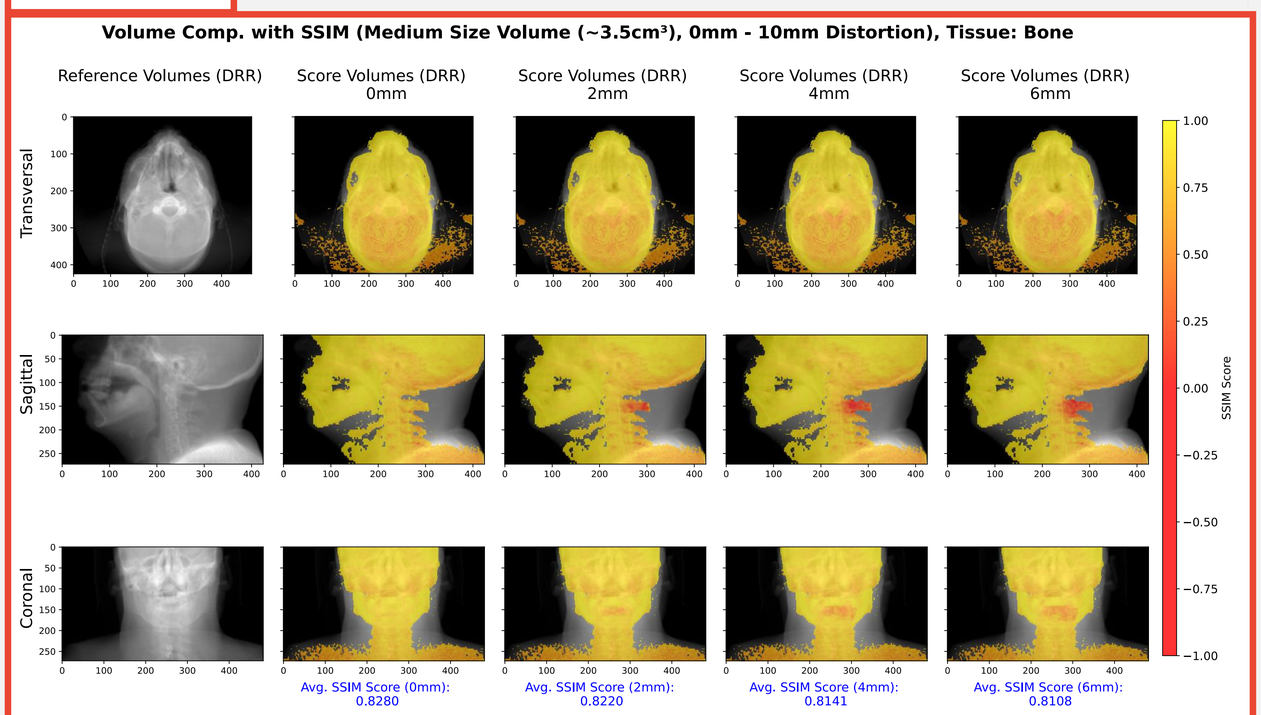

Figure 4: Test in which a volume (sagittal view at (280, 150)) is artificially distorted laterally along the transversal axis. The higher the SSIM score the higher the similarity.

Discussion:

Key Findings:

- SSIM and 1D-DTW similarity measures implemented in the custom algorithm show promise in detecting distortions in the sCTs.
- Custom algorithm is efficient in excluding irrelevant regions from the similarity measurements and in visualising the distortions (through Digitally Reconstructed Radiograph (DRR) projection method).
- Scores generated by SSIM and 1D-DTW varied in each subject. Thus, from this work, a quality threshold for assessing the quality of the sCT could not be established.

Limitations:

- High difference in mean pixel intensity negatively influences proposed similarity measures.
- SSIM is susceptible to structures with low contrast (e.g. soft tissue structures as can be seen in the CBCT and sCT in Figure 1).

[1] *Structural Similarity Index Measure* [2] *Dynamic Time Warping*

References:
[1] *Thummerer, Adrian, et al. "Comparison of CBCT based synthetic CT methods suitable for proton dose calculations in adaptive proton therapy." Physics in Medicine & Biology 65.9 (2020): 095002.*
[2] *Nesteruk, Konrad P., et al. "CT-on-Rails versus in-room CBCT for online daily adaptive proton therapy of head-and-neck cancers." Cancers 13.23 (2021): 5991.*

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