Automated Metal Artifact Segmentation for Extended CT in Radiation Therapy Planning: A Feasibility Study

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Introduction

Metal hip prostheses cause severe streaking artifacts in CT scans, obscuring nearby anatomy and degrading dose calculation accuracy. Because bright streaks overlap bone in intensity, manual density overrides can be time-intensive and lack standardization.

Our institution images with an extended CT scale, allowing high-density metals to be observed at its true HU values. We have developed an application that automatically detects metal implants, separates bone from artifact, and classifies the tissue underlying each artifact.

Testing on four patients with unilateral and bilateral implants shows reliable detection with minimal user input, reducing override time from roughly an hour to under three minutes and demonstrating improved efficiency and standardization.

Star-Profile Algorithm Overview

Detect Metal → **Segment Dark Artifacts** → **Classifying Bone vs. Bright** → **Classifying Artifacts**

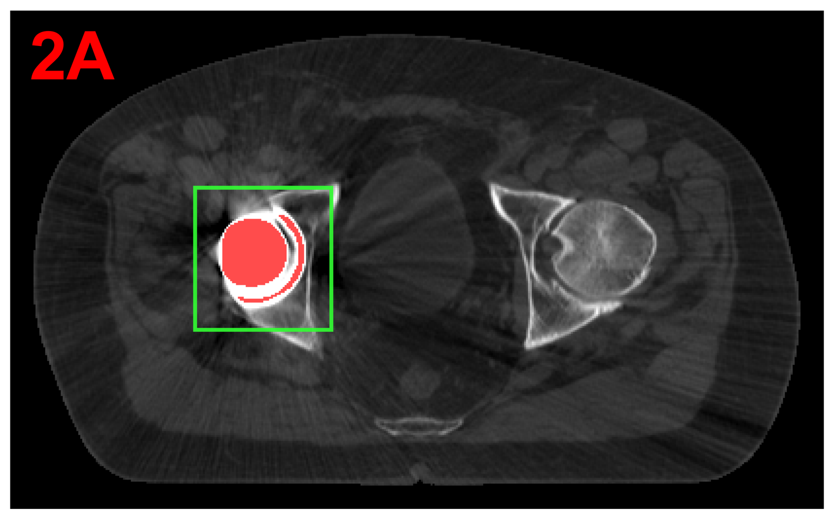

Figure 2A. Automatic metal detection (red) with **adaptive** thresholding per slice.

- Star (line) profiles are cast from each implant on every slice.
- Metal threshold adapts per slice using FW75% of the peak profile HU.

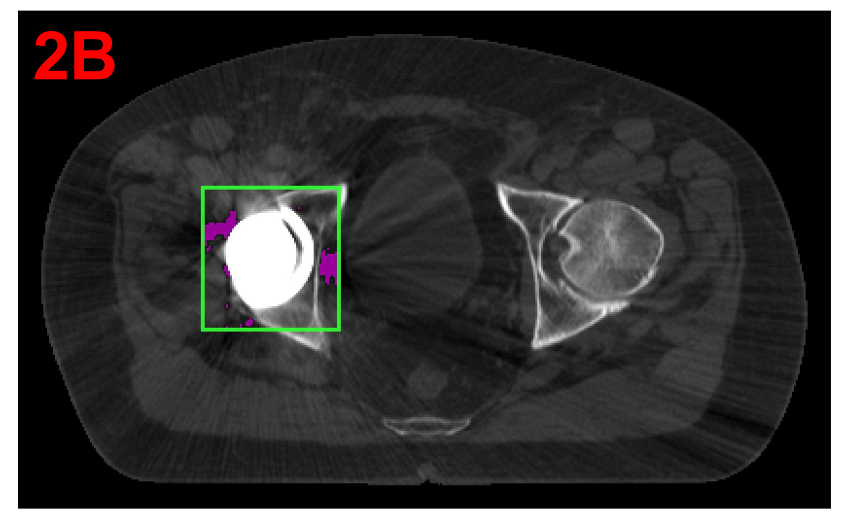

Figure 2B. Dark artifacts (segmented) with an adjustable thresholding range (-1024 to -150 HU).

- As dark artifacts overlap with no other tissue or bone, this is seen to be reliable.

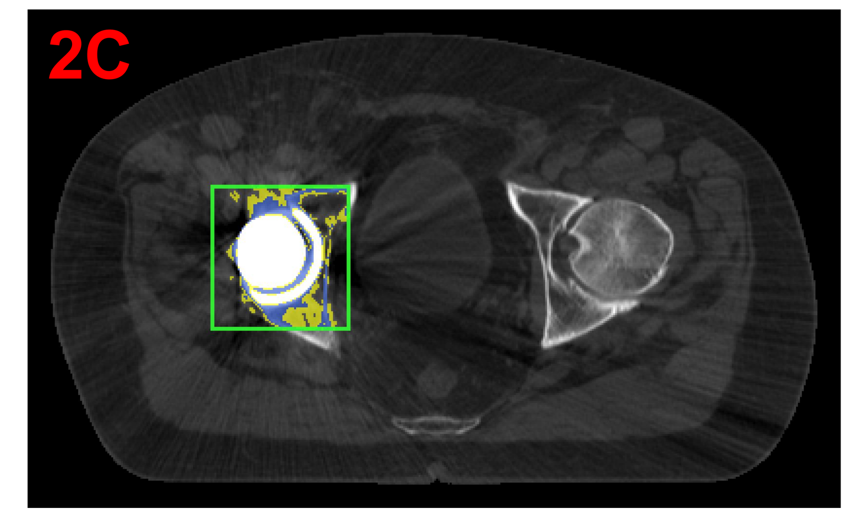

Figure 2C. Bright artifacts (yellow) and bone (blue) are contoured based on the shape of the line profiles.

- Bright voxels tend to **overlap** bone in intensity.
- Each voxel is determined based on radial profiles casted from the implant's center (see Methods).

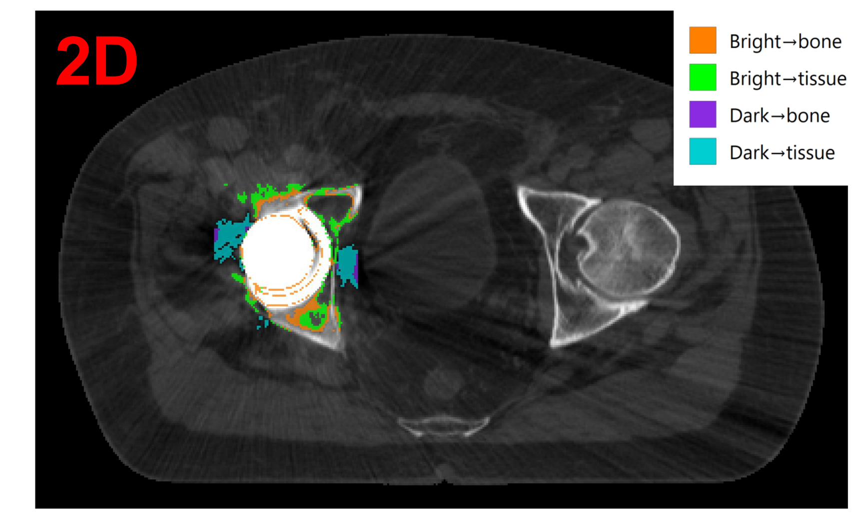

Figure 2D. Each artifact is assigned either tissue or bone based on its neighboring voxels.

- These artifacts are classified based on the HU of their surroundings (see Methods).

How Metal Artifacts Form

- **photon starvation**: high attenuation of x-rays in the implant causes insufficient x-rays to reach the detector, and
- **beam hardening**: lower-energy photons are absorbed more easily than higher-energy photons, causing massive streaking

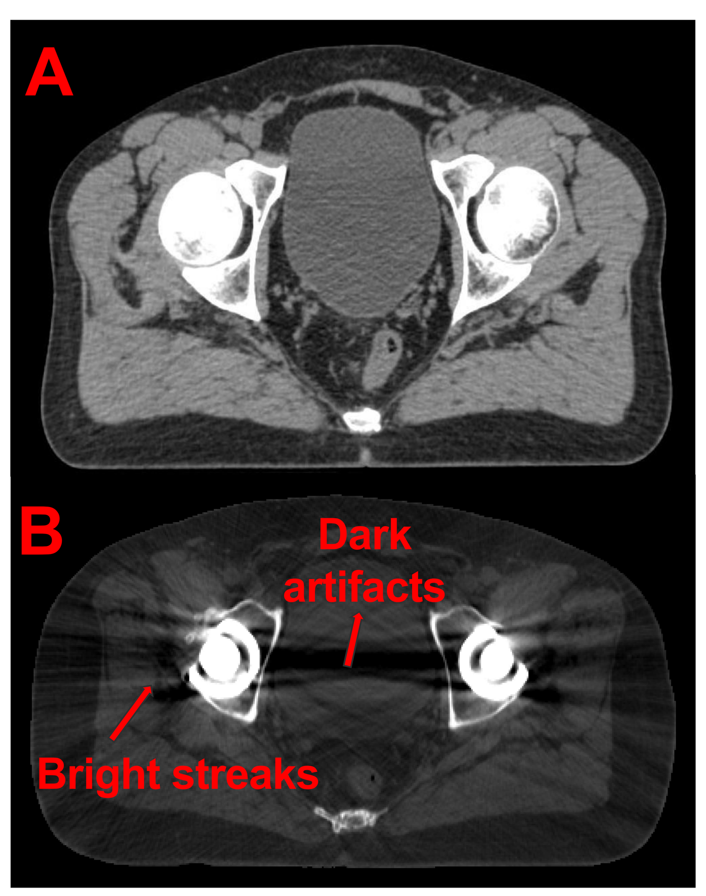

Figure 1. (A) Normal CT scan showing clear visualization of bone and soft tissue. (B) Middle slice of a bilateral hip replacement.

In treatment planning, CT images provide electron density measurements for dose calculations. However, these artifacts cause **inconsistencies** in the CT data.

Overriding the metal and artifacts to their respective **electron densities** can help streamline clinical workflow and improve dose calculation accuracy.

Methods: Classifying Bone vs. Bright

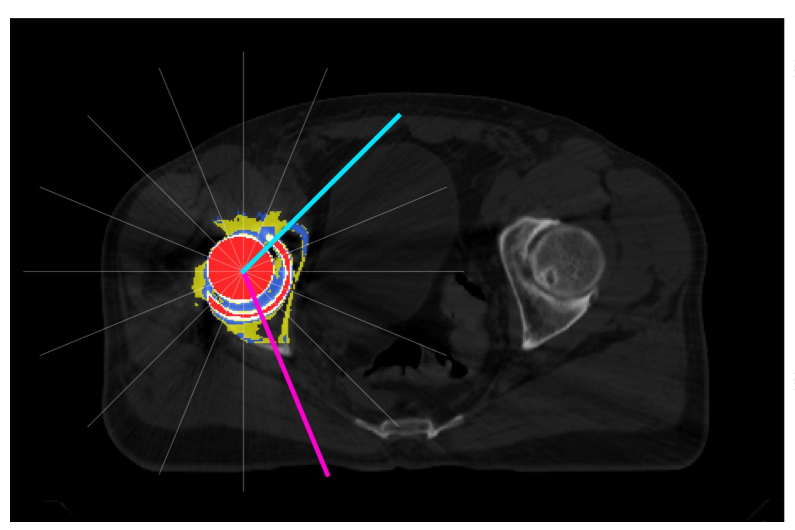

Figure 3. 16-line profiles stemming from the implant's center in this specific slice. Shown are metal (red), bone (blue), and bright artifacts (yellow).

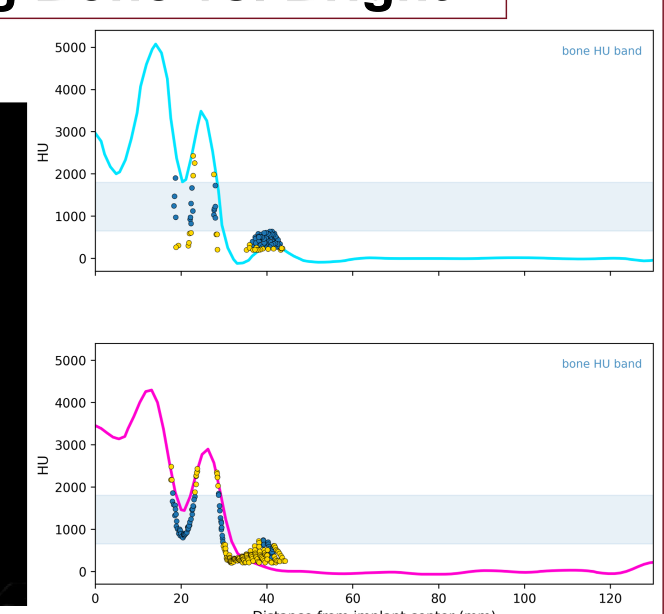

Figure 4. Two example line profiles from Figure 3. Each dot is a voxel plotted to its nearest line profile.

Feature	Measures	Bone	Bright
Bone HU range	Brightness of voxel	Within range	Outside range
Peak width	Width of the bump in the line profile	Wide (> 3mm)	Narrow (<2mm)
Smoothness	Variance of the slopes	Low variance	High variance
Gradient	Average of the slopes	Low average	High average

Table 1. Criteria for classifying whether a voxel is a bright artifact or bone. Peak width, smoothness and gradient criteria are measured over a 10 mm stretch of the line profile centered on each voxel. Each feature is given an adjustable weight.

Methods: Classifying Artifacts

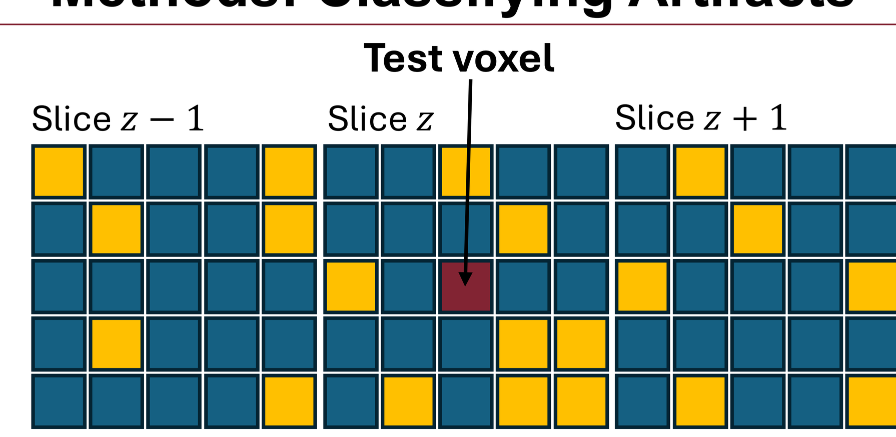

Figure 5. For each artifact voxel (red), a 5x5x3 patch is formed spanning the voxel's own slice and the slices above and below it.

- Neighboring voxels are binned into adjustable HU ranges of bone (yellow) and tissue (blue), and the test voxel is set to the majority winner.

Results and Future Work

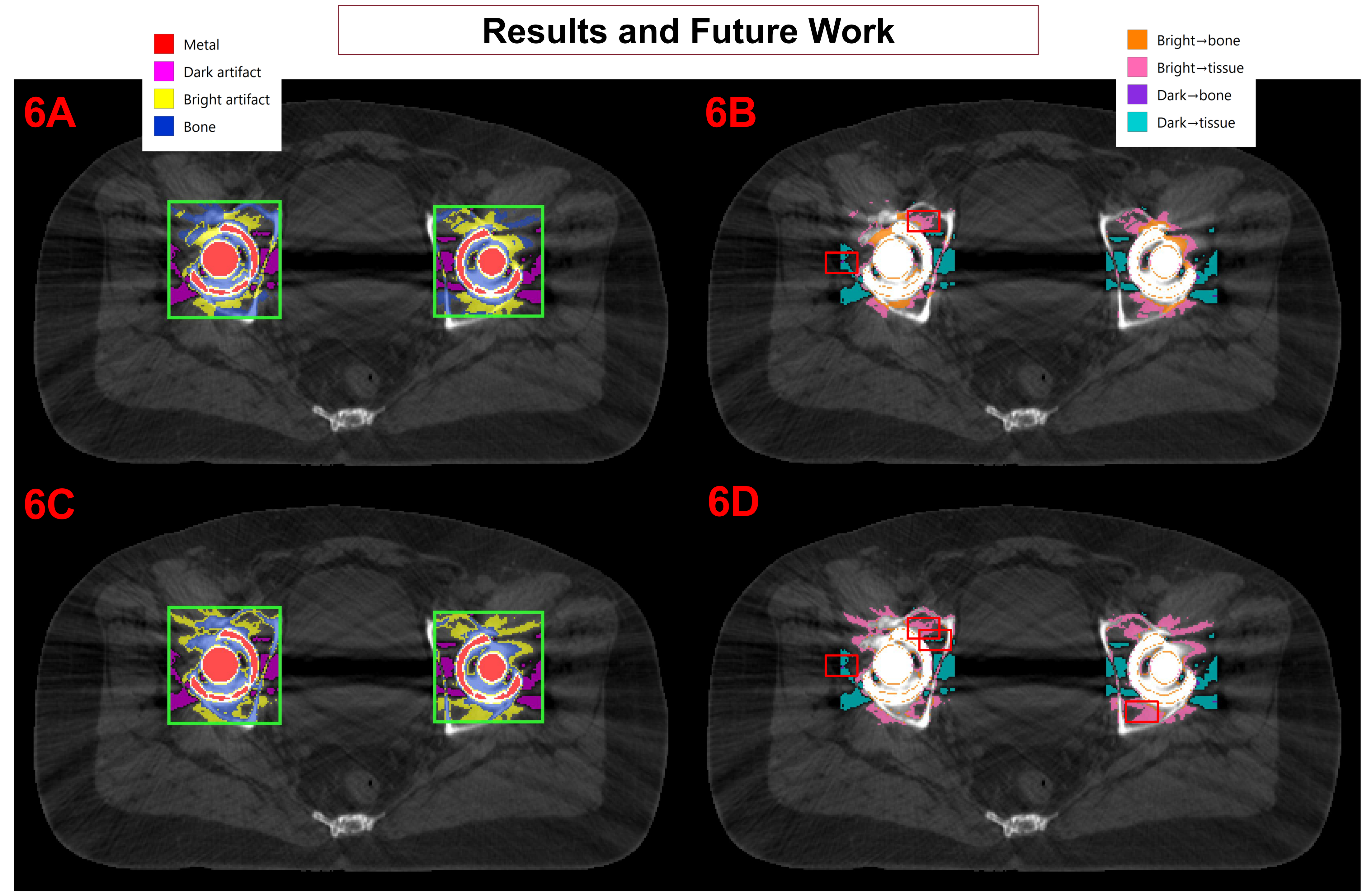

Figure 6. Middle slice of a bilateral hip replacement segmented by two algorithms: the star-profile algorithm (A, B) and nested Boolean thresholding (C,D). Areas of failed distinction are shown red.

- The fourth stage classifies each artifact's voxel as overlying bone or soft tissue for automatic density overrides, but it fails to resolve some regions shown in Figure 6.
- Both the star-profile algorithm and basic intensity thresholding effectively delineate metal and dark artifacts because of their distinct and non-overlapping HU ranges.
- The two methods **diverge** in how they separate **bone** from **bright artifacts**.
  - Nested Boolean logic contours bone first and treats remaining bright voxels as artifacts
  - Star profile analysis combines both bone and bright artifacts into one set for classification.
- Future work will include **whole-slice segmentation**, integration of **metal-artifact reduction** (MAR) methods for visualization of bone, and validation of these algorithms against different types of implants.

References and Acknowledgements

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