Metal Artifact Removal in C-arm Cone-Beam CT

Group 4

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Project mentors/advisors

- Jeffrey Siewersden, PhD
- Martin Radvany, MD (Interventional Radiology)
- Tina Ehtiati, PhD (Siemens Healthcare)

Mission

Construction of **brain phantoms** and acquisition of CT images for a **quantitative data analysis** and assessment of (a) **image quality** and (b) **metal artifact removal** algorithm accuracy.

Technical Background

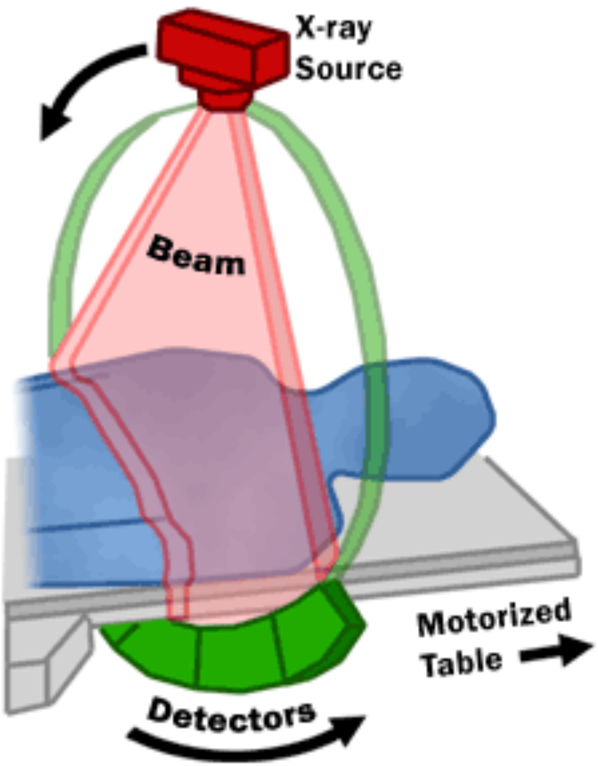


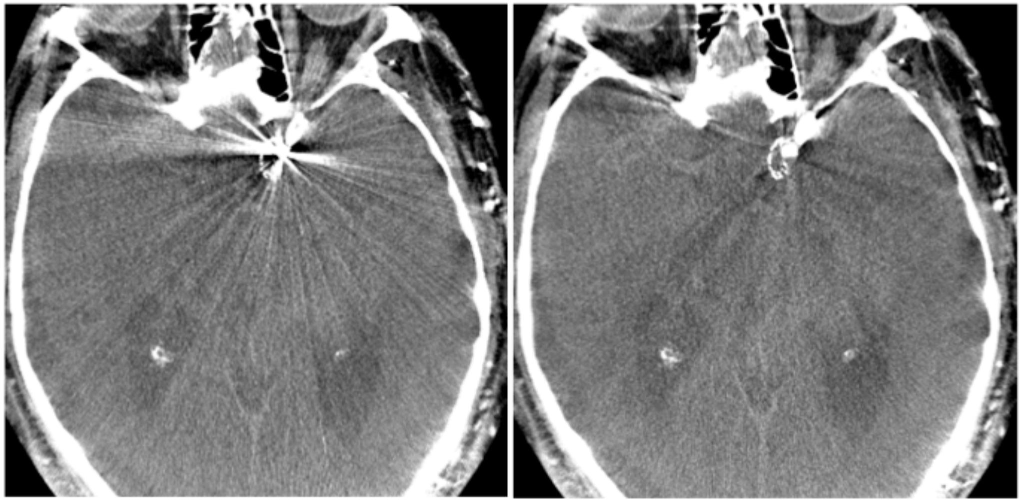
Image provided by fda.org

- X-ray computed tomography (CT) is an imaging modality that uses reconstruction methods to create cross-sectional images from x-ray attenuation data.

- *Artifacts* is a term that refers to any discrepancy between attenuation data of the reconstructed image and the true attenuation of the object.

Technical Background (cont.)

- Metal artifacts are artifacts caused by the presence of dense metal materials in the object. These cause a degradation on the image quality.

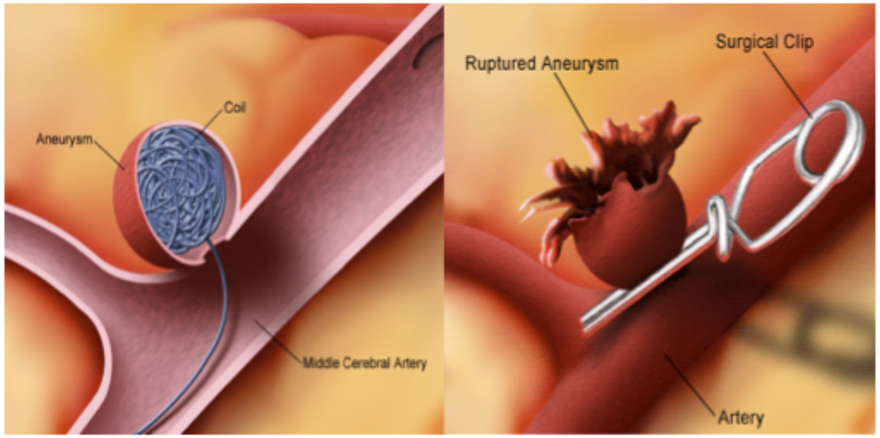


CT image of coil before and after MAR algorithm application
Image provided by Radvany, MD

- Metal Artifact Removal (MAR) algorithms have been developed to reduce and/or remove these artifacts, and are ready for clinical testing.

Clinical Background

- Neurovascular interventions are minimally invasive procedures for treatment of: aneurysms, intercranial stenosis, and AVMs



Coil procedure (left) and clipping treatment (right) for cerebral aneurysm.
Image provided by hopkinsmedicine.org

- Treatment of these diseases, which include the use of clips, coils, stents and other metal-based materials, depend on CT imaging acquisition in the surgical environment.

Introduction → **Background** → Deliverables → Approach → Schedule → Dependencies → Plan

Significance

- Optimizing image quality through MAR algorithms will ensure a safer, more accurate use of CT imaging in the surgical environment.

Available resources

- Hollow brain phantom ('scarecrow'), brain-equivalent inserts, and other materials
- Experimental Imaging bench: CT imaging system available at the I-STAR lab, JHU Medical Campus
- Zeego/Axiom Artis Zee: Siemens C-arm, cone-beam 3D imaging system available at the JHU Medical Campus

'scarecrow' brain phantom
Image provided by the I-star lab

C-arm Cone-Beam CT
Image provided by Siemens Healthcare

Deliverables

- **Phantom Construction**
  - Minimum: solid metal sphere and contrast vasculature
  - Expected: coils and/or clips and contrast vasculature
  - Maximum: liquid embolic system (“ONYX”) and contrast vasculature
- **Image Acquisition**
  - Minimum: Experimental Imaging Bench
  - Expected: Zeego / Axiom Artis Zee Imaging system
  - Maximum: Writing algorithm capable of transferring data between the Experimental Imaging bench and the Zeego console.
- **MAR Algorithm**
  - Minimum: run and implement algorithm
  - Expected: adapt and extend for performance improvement
  - Maximum: suggest and implement algorithm improvements

Deliverables (cont.)

- **Data Analysis: Image Quality**
  - Minimum: quantitatively measure contrast resolution (CNR)
  - Expected: measure spatial resolution, artifact distortion magnitude
  - Maximum: individual artifact-specific measurable parameters

- **Data Analysis: Segmentation Accuracy of the MAR algorithm**
  - Minimum: application of segmentation algorithm on acquired data
  - Expected: quantitatively measure segmentation accuracy
  - Maximum: segmentation algorithm improvement and suggestions

Technical Approach: Dependent Parameters

Phantom Construction:

- *Metal fillings*:
  - Diameter
  - Volume
  - Density
  - number and shape of coils and clips
- *Simulated vasculature*:
  - number of vessels
  - contrast
  - volume and shape
  - material

Image Acquisition:

- Energy of beam (kVp)
- Number of projections
- Dose
- Tube current
- Pitch
- Acquisition time

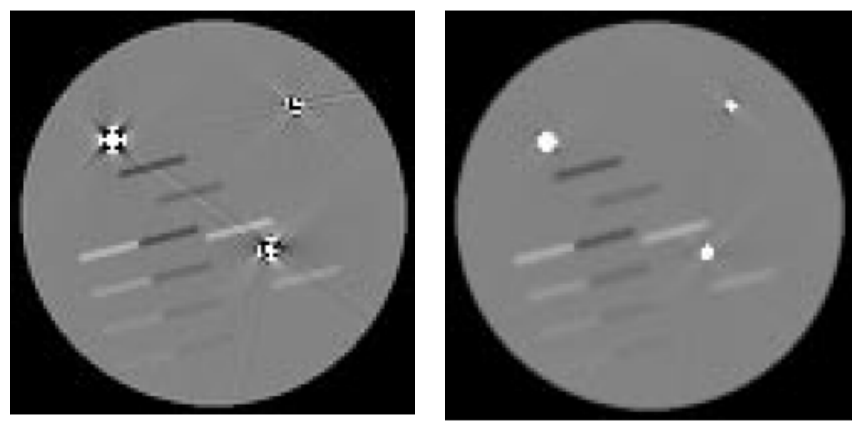
Technical Approach: Measurable Variables

Data Analysis:

- Contrast resolution
- Spatial resolution
- Signal-to-noise ratio
- Artifact magnitude

MAR Methods:

- Comparison between known volume/shape of metal objects and the segmentation



MAR segmentation on spheres
Image provided by De Man, et.al.

Schedule/Responsibilities

Task Name	Week number														
	3	4	5	6	7	8*	9	10	11	12	13	14	15	16	Responsibilities
1. First stage															
1.1 construction of phantom: metal sphere															both
1.2 image acquisition: bench															both
1.3 image acquisition: zeego															both
1.4 data analysis															Marta
2. Second stage															
2.1 construction of phantom: coils and/or clips															both
2.2 image acquisition: bench															both
2.3 image acquisition: zeego															both
2.4 data analysis															Marta
3. Third stage															
3.1 construction of phantom: ONYX															both
3.2 image acquisition: bench															both
3.3 image acquisition: zeego															both
3.4 data analysis															Marta
4. CIS course key dates															
4.1 project plan															Cay
4.2 seminar															both
4.3 project checkpoint															Cay
4.4 poster session															Cay
4.5 final report															

Dependencies: Experimental Imaging bench

Dependency: Availability

- **Resolution:** Image acquisition will be done in a two-week period once in every project stage. Scheduling depends on Dr. Siewersden and lab members.
- **Backup-plan:** Zeego system will be used instead.
- **Resolved by:** End of each brain phantom construction period.
- **Affects:** Image acquisition for image quality assessment.

Dependency: Training/Supervision

- **Resolution:** Training of equipment will occur during 2/17-2/23. Lab member supervision (if required) will be scheduled previously.
- **Backup-plan:** Zeego system will be used instead.
- **Resolved by:** 2/17-2/23.
- **Affects:** Image acquisition for image quality assessment

Dependencies: Zeego/Axiom Artis Zee

Dependency: Availability

- **Resolution:** Image acquisition will be done in a three-week period once in every project stage. This imaging system is in clinical use and therefore has an undependable schedule. Scheduling depends on Dr. Ehtiati.
- **Backup-plan:** Bench imaging system will be used instead.
- **Resolved by:** The end of each brain phantom construction period.
- **Affects:** Image acquisition for MAR assessment.

Dependency: Training/Supervision

- **Resolution:** Supervision (by Dr. Ehtiati or technician) will be needed during each image acquisition.
- **Backup-plan:** Bench imaging system will be used instead.
- **Resolved by:** The end of each brain phantom construction period.
- **Affects:** Image acquisition for MAR assessment.

Dependencies: Brain phantom and materials

Dependency: Availability

- **Resolution:** The I-STAR lab already is in possession of the phantom (just available to us this semester) and insert materials (brain-equivalent jello, soft-tissue inserts, coils, clips, etc)
- **Backup-plan:** If the material is not available in the lab, then a request will be made to Dr. Siewersden for ordering at least two weeks prior of its intended use.
- **Resolved by:** The end of each image acquisition period.
- **Affects:** Further image acquisition.

Dependencies (cont.)

- Software available in bench and Zeego
- Travel to/from Homewood/Medical Campus
- Availability of Dr. Radvany and lab technicians
- Permissions constraints (these will be investigated and requested if needed):
  - Permission to operate Zeego and/or bench
  - Access to the hospital interventional radiology suite
  - Access to the I-STAR lab

Management Plan

- Weekly meetings (members and mentors) every Thursday at 8:00 am
- Weekly meetings (members) every Saturday and Monday
- All documents related to the project will be available in a Dropbox account accessible to both members
- The web page will be edited weekly (every Saturday)
- A sign-up sheet document will keep track of the members' hours and tasks

References

- [1] Barrett, J. F., and N. Keat. "Artifacts in CT: Recognition and Avoidance." Radiographics 24.6 (2004): 1679-691. Print.

- [2] Meyer, Esther, Rainer Raupach, Michael Lell, Bernhard Schmidt, and Marc KachelrieB. "Normalized Metal Artifact Reduction (NMAR) in Computed Tomography." National Center for Biotechnology Information. U.S. National Library of Medicine, n.d. Web. 09 Feb. 2013.

- [3] Prell, D., Y. Kyriakou, T. Struffert, A. Dorfler, and W. A. Kalender. "Metal Artifact Reduction for Clipping and Coiling in Interventional C-Arm CT." American Journal of Neuroradiology 31.4 (2010): 634-39. Print.

- [4] Prell, Daniel, Yiannis Kyriakou, Marcel Beister, and Willi A. Kalender. "A Novel Forward Projection-based Metal Artifact Reduction Method for Flat-detector Computed Tomography." Physics in Medicine and Biology 54.21 (2009): 6575-591. Print.

- For further references, refer to the project web page.

Thank you.

Questions?