



Radiographic Radiomics Phantom Development

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Overview

- Problem Statement
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- Product Design Specification
- Preliminary Designs
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Fig 1. Design team photo. Pictured from left to right: Ava Hodgson, Presley Stellflue, Pierson Trapskin, Sonja Pioneck, Allie Ma, and Matthew Casas.

Problem Statement

Client Problem Statement:

- Radiomic features vary across different imaging systems and acquisition settings
- Existing imaging phantoms lack the varied, tissue-like textures needed for reliable comparison

Goal:

- Develop a modular phantom with a removable core for both head and abdomen imaging
- Incorporate multiple reproducible, tissue-like textures that are visible in CT imaging

Expectation:

- Enable reliable comparison of radiomic measurements across imaging systems
- Produce consistent, repeatable measurements over multiple years of use



Background

- Technology
 - Cone Beam Computed Tomography (CBCT)
 - Single rotation
- Importance & Advantages
 - Reduced radiation
 - General purpose

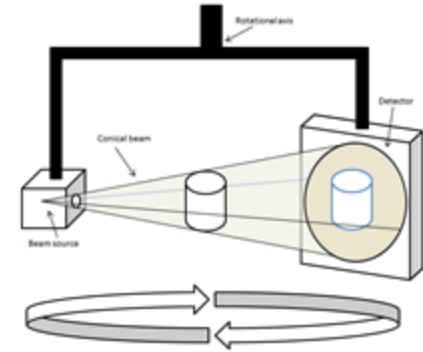


Figure 2: Cone Beam Computed Tomography Technology



Figure 3: Real-Life Example of CBCT



Background

- What is Radiomics?
- CT scanners can produce variability between scans & systems.
 - Phantom measurements create reproducibility [9].
- Materials of known/measurable density for calibration [3].

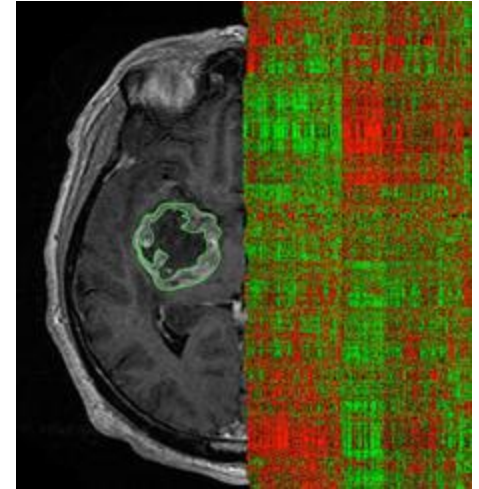


Figure 4: Radiomics in Medical Imaging



Competing Solutions

- ACR CT 464 Phantom [6]
 - Established measurements for scanner performance & image quality.
- Biological Phantom [6]
 - CT image reconstruction algorithms.
- Low-Cost 3D-Printed PLA Phantom [8]
 - Low-cost reproduction.



Figure 5: ACR CT 464 Phantom - Sun Nuclear



Figure 6: 3D-Printed PLA Phantom



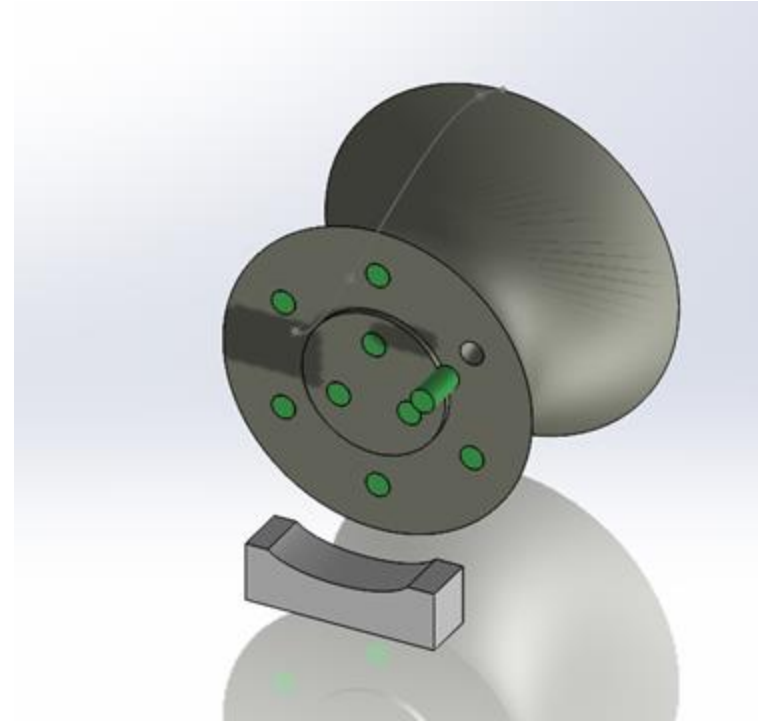
Design Specifications

- Incorporate a variety of different textures to represent the variability and nonhomogeneous characteristics of real human tissue.
- Outer shell is relative to the size of a human abdomen and inner core is relative to the size of human head
 - The head should have a diameter of 16 cm by 25cm height, and the abdomen should have a diameter of 38cm by 20cm height.
- Withstand research trials and provide consistent results through repeated usage.
 - Ideally the phantom should last for upwards of 5 years



Design 1 (Parabolic)

- **Effectiveness:** Curved shape gives realistic anatomical geometry, but fewer insert positions than Design 2
- **Ease of Use:** Compact and easy to position during CT acquisition
- **Cost:** Uses the least material, so raw material costs stay low
- **Ease of Production:** Organic curves need multi-axis machining or a tricky 3D print setup
- **Modularity:** Has removable inserts, but limited surface area caps how many tissue modules fit
- **Safety:** Curved exterior can roll or tip unless it's locked into a custom base



Design 2 (Elliptical)

- **Effectiveness:** A dense grid of insert channels supports thorough radiomic feature testing at different radial distances
- **Ease of Use:** A custom-contoured base cradle keeps it stable and simple to align on the scanner couch
- **Cost:** Simple cylindrical body, but many tight-tolerance holes add machining time and cost
- **Ease of Production:** The body is straightforward to make, but the large array of precise insert holes takes a lot of machining time
- **Modularity:** Inner and outer ring slots give lots of flexibility to swap and test texture samples
- **Safety:** The flat, fitted cradle base keeps it from rolling during use

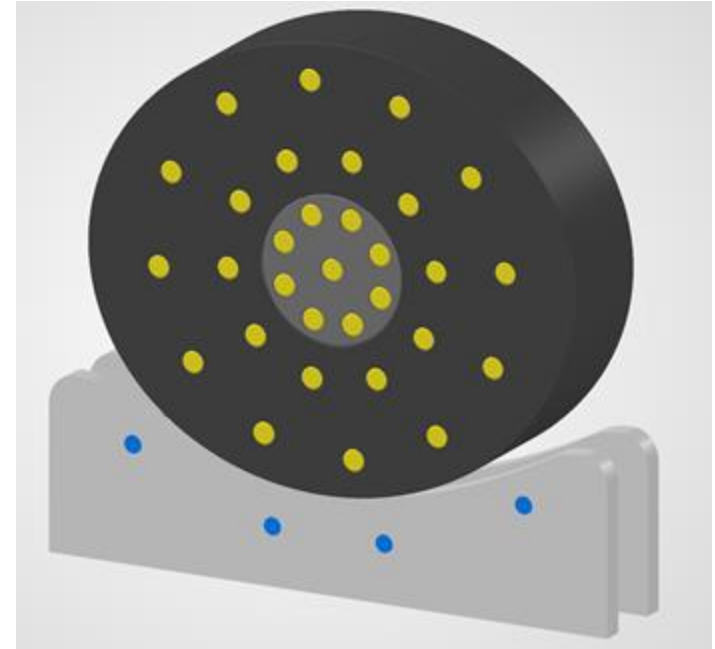


Figure 8: Force plate insoles



Design 3 (Rectangular)

- **Effectiveness:** Insert arrangement limits sampling density and fewer inserts than Design 2
- **Ease of Use:** Rectangular shape is bulky and more challenging to lift and align properly
- **Cost:** Substantial volume increases fabrication costs
- **Ease of Production:** Planar faces and rectangular geometry makes design and assembly simple
- **Modularity:** Insert slots only on the outer rectangle box, interior ROI cannot be tested
- **Safety:** Flat rectangular base prevents rolling, but increased mass create risks

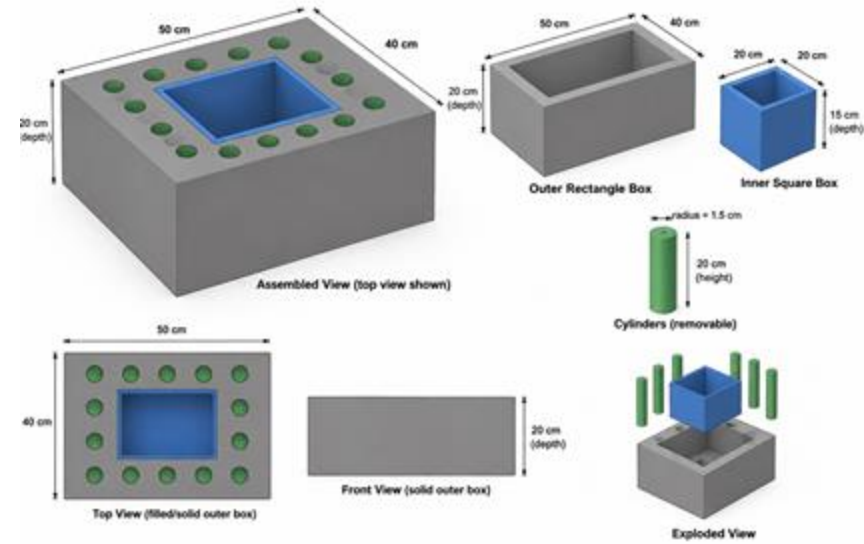


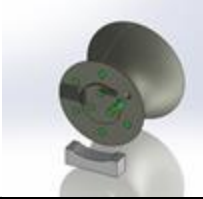
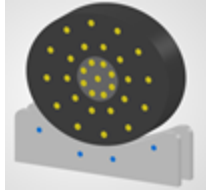
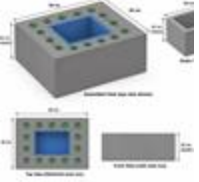
Figure 9: Design 3 (rectangular)



Design Matrix

- Chosen criteria
- Design 1 score standout
 - Cost-Efficient
- Design 2 score standout
 - Effective, Broad Use, & Safe
- Design 3 score standout
 - Easy to Produce

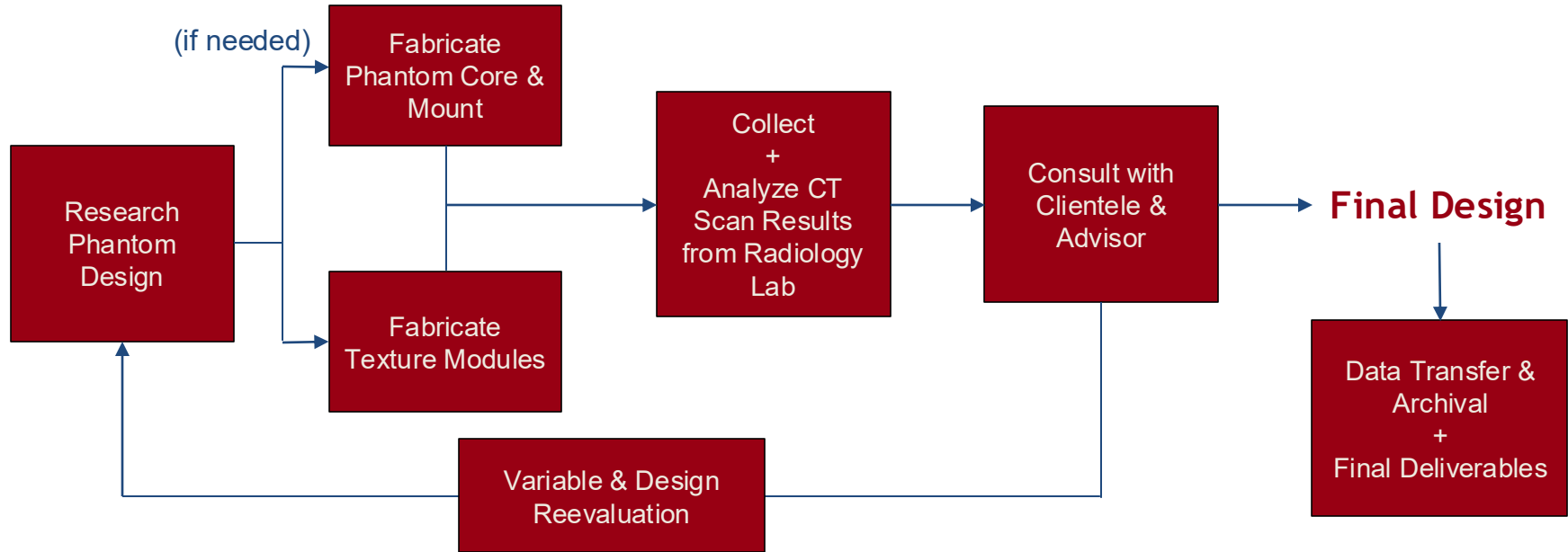
Table 1: Design matrix for data collection modalities

Criteria	Criteria Weight	Design 1 	Design 2 	Design 3 
Effectiveness	[25]	$\frac{4}{5} \rightarrow 20$	$\frac{5}{5} \rightarrow 25$	$\frac{3}{5} \rightarrow 15$
Ease of Use	[20]	$\frac{4}{5} \rightarrow 16$	$\frac{4}{5} \rightarrow 16$	$\frac{3}{5} \rightarrow 12$
Cost	[15]	$\frac{4}{5} \rightarrow 12$	$\frac{3}{5} \rightarrow 9$	$\frac{3}{5} \rightarrow 9$
Ease of Production	[15]	$\frac{2}{5} \rightarrow 6$	$\frac{3}{5} \rightarrow 9$	$\frac{4}{5} \rightarrow 12$
Modularity	[15]	$\frac{3}{5} \rightarrow 9$	$\frac{4}{5} \rightarrow 12$	$\frac{3}{5} \rightarrow 9$
Safety	[10]	$\frac{2}{5} \rightarrow 4$	$\frac{4}{5} \rightarrow 8$	$\frac{3}{5} \rightarrow 6$
Total	[100]	67	79	63

Testing Procedures

1. Conduct a water scan (for control).
2. Insert texture modules into phantom core. Align the phantom in the sagittal, coronal, and axial planes while securing the phantom to the CT table.
3. Conduct axial scan using increments of 2 mm.
4. Analyze CT images for CNR and uniformity. Compare texture modules with live tissue samples.

Future Work



Acknowledgments



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Thank you!



References

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