Automated Low Contrast Detection for ACR MRI Phantom Quality Assurance

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Purpose

To create an algorithm for low contrast detection in the American College of Radiation (ACR) magnetic resonance imaging (MRI) phantom during quality assurance.

Methods

The low contrast module consists of four slices, each with 10 sets of three disks arranged in a circular spoke pattern. Each spoke is considered a pass if all three disks are visible with a maximum of 40 points possible.

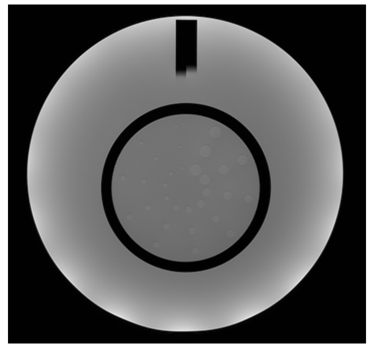

Figure 1 (Left) ACR MRI quality assurance phantom. (Right) T1 slice of the low contrast module.

Our low contrast detection works as follows (see Figure 2):

1. Image is binarized using histogram thresholding to remove background.
2. Connected components are identified and labeled.
3. A binary mask of the inner disk is generated by thresholding the labeled image.
4. The mask is used to remove the outer disk.
5. The center of gravity (COG) of the binary mask is calculated, which represents center of the inner disk.

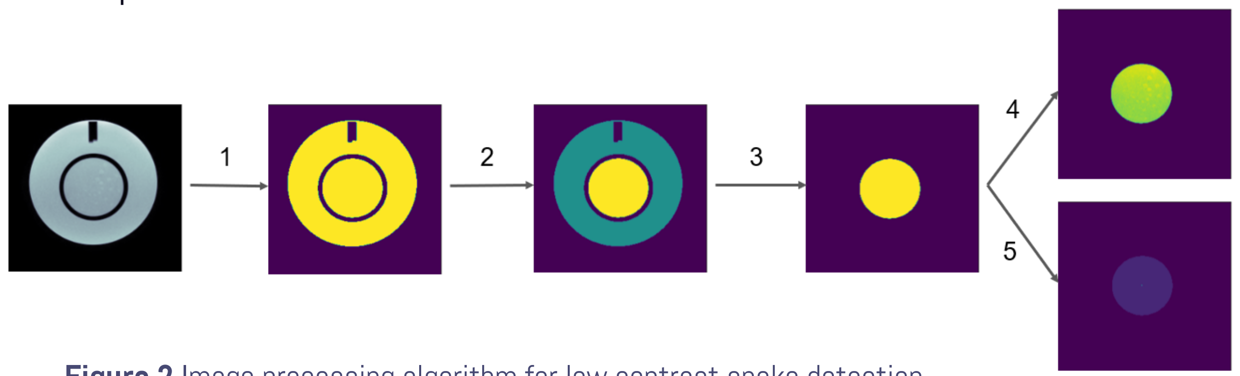

Figure 2 Image processing algorithm for low contrast spoke detection.

6. From the COG, a radial profile is generated at a designated angle, and the image intensity along this profile is sampled into a 1D array.
7. The 1D profile (red line in Figure 3) is then matched against a predefined 1D template (blue line in Figure 3), which is created based on the known geometry of the phantom.
8. The profile and template undergo an element-wise multiplication, and the products are summed.
9. If the summation surpasses a certain threshold (e.g. 0), it signifies that the profile corresponding to the specified angle has passed.

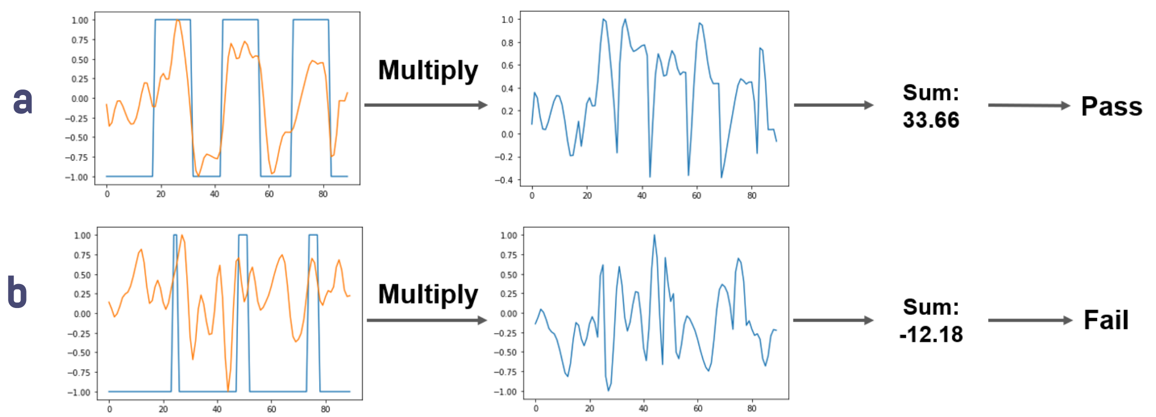

Figure 3 (a) Example of a passing low contrast profile. (b) Example of a profile where not all spokes are visible.

Results

Five MRI datasets were taken during quality assurance and analyzed manually by conventional measurement. A Rose model-based algorithm[1] for low contrast, which simulates the performance of the human eye on an absolute scale, was also compared. Spoke pass rates generally agreed with human quality assurance measurements, showing differences of 2.7±4.2. Results also compared more favorably than the Rose model (visibility threshold of 0.20), which showed differences of 4.7±4.3 using the same datasets. Average algorithm run time was 4.3 seconds per dataset.

Scorer	Dataset[a] #1	#2	#3	#4	#5	Average Difference between Experts and Algorithm
Expert 1	39	37	40	40	39	
Expert 2	38	37	40	40	39	
Automated Low Contrast	39	40	35	32	35	2.7 ± 4.2
Rose-model[b]	37	38	30	35	31	4.7 ± 4.3

[a] *Out of 40 possible points*

[b] *Threshold = 0.2*

Table 1 Low contrast test result comparisons between the Rose model algorithm and our automated low contrast algorithm.

Discussion

In this study we developed an automated code to perform the low contrast detectability test on the ACR MRI phantom. The outcomes are in line with the results manually obtained by two experts. Using the automated algorithm can help mitigate intra-rater and inter-rater variability, resulting in more reliable and consistent outcomes.

Future work consists of further refining the algorithm to enhance its precision, robustness, and integration into an automated solution for our clinic's quality assurance program.

Conclusion

We present a novel algorithm for automatically analyzing the ACR MRI phantom low contrast module that can be intergrated into a clinic's QA program.

References

[1]Albert Rose, "The Sensitivity Performance of the Human Eye on an Absolute Scale*," J. Opt. Soc. Am. 38, 196-208 (1948)

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