On the Impact of Image Rotation on Quantitative Textural Features in Radiomics Analysis

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INTRODUCTION: Reproducibility and consistency of textural features play a key role in quantitative image analysis. In radiomics analysis, it is important that the radiomic features extracted from the organ-of-interest quantitatively behave the same regardless of how the organ is oriented in space. Lack of rotational invariance in quantitative evaluation of image textural features means that the feature value will be sensitive to the angular sampling technique employed in computing the feature.

AIM: In this study, we investigated the impact of image rotation on the quantitative values of 95 radiomic features from 6 different textural radiomic feature categories, using an in-house developed software and a 3D gradient digital phantom.

METHOD: A 3D computational phantom was developed with the following specifications: 4 axial slices with 32×32 (2×2×2mm^3) voxels, 4 corner-to-corner intensity gradients in 2 orthogonal directions with voxel intensities ranging from 1 to 64. The gradient phantom (Fig. 1) was rotated 90 times about the baseline (1-90 Deg., using nearest-neighbor interpolation technique). An in-house software (ROdiomX) validated by the IBSI (Image-Biomarker-Standardization-Initiative) was used to compute 95 textural features from the following 6 textural feature categories (3D with 27 directions): Gray-Level-Co-occurrence (GLCM: 25-features), Gray-Level-Run-Length (GLRLM: 16-features), Gray-Level-Size-Zone (GLSZM: 16-features), Gray-Level-Distance-Zone (GLDZM: 16-features), Neighborhood-Grey-Tone-Difference (NGTDM: 5-features), and Neighboring-Grey-Level-Dependence (NGLDM: 17-features). Coefficient of variance (CV), intra-class correlation coefficient (ICC, two-way random-average-score), and mean absolute deviation (MAD) were calculated to measure dispersion of each feature around the baseline value.

RESULTS: ICC values for all feature categories were less than 0.40 (ICC<0.40, poor). Figure-2A to 2F demonstrate MAD rankings for different textural features within their feature categories. The CV is a useful statistic for comparing the degree of variation from one data series to another, even if the means are drastically different from one another. Analysis results implied that GLDZM, NGTDM, NGLDM, GLRLM, GLSZM, and GLCM are the least to most impacted ($\overline{CV}$= 1.75, 2.23, 2.96, 3.51, 4.03, and 6.02 respectively) feature categories against image rotations.

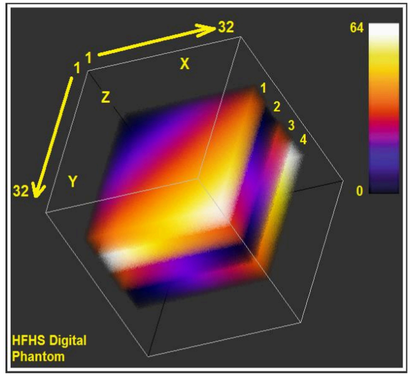

Figure-1: Three dimensional view of the 3D digital gradient phantom. The phantom has four slices with four corner-to-corner gradients with two orthogonal directions for voxel intensities ranging from 1 to 64

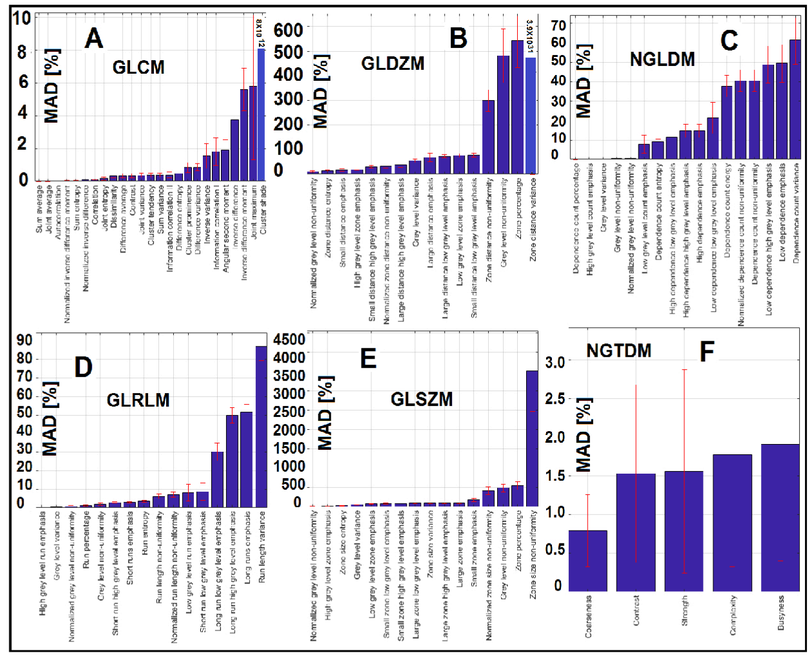

Figure-2A-2F demonstrate the MAD rankings for textural features for six feature categories

As shown in Figure-2A-2F, features from GLSZM, NGTDM, GLSZM, GLDZM, GLCM, NGLDM, and GLRLM categories are affected more uniformly against rotations respectively. This study investigated the sensitivity, ranking, and variation of 95 textural features from 6 different feature categories against rotation. None of the feature categories were found to be rotation-invariant. Further investigations using more complex digital phantoms with different levels of gradient and directionality, different rotation-interpolation, and feature aggregation techniques are needed.

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CONCLUSIONS: This study investigated the sensitivity of 95 textural features from 6 different feature categories against rotation. Lack of rotational invariance suggests that specific protocols for angular sampling in computation of these features is necessary to reduce variation among different algorithms used to compute the same features.