RОdiomX: A New Validated Software for the Radiomics Analysis of Medical Images in Radiation Oncology

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INTRODUCTION:

- Validation of quantitative radiomics information and implementation of computational models following a standard (e.g. Image-Biomarker-Standardization-Initiative, IBSI) are critical first steps toward reliable computation of radiomics features, which can be verified at multiple institutions.
- It is only after radiomics features computed using consistent procedures and benchmarked using 'ground-truth' data that can be used in analysis of patient datasets towards the goal of reliable radiomic feature association with outcomes.

AIM:

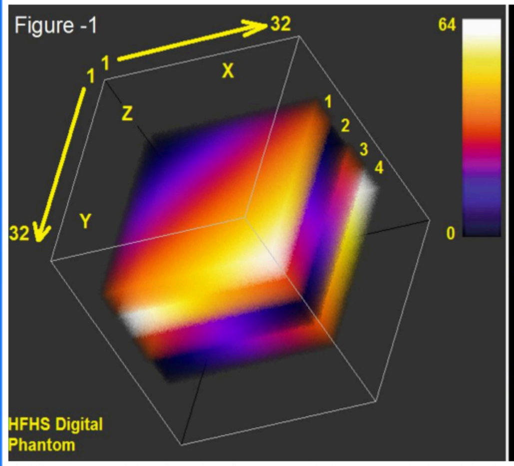
Here we introduce an in-house-designed software platform (RОdiomX) for the radiomics analysis of medical images in radiation oncology. RОdiomX is a MATLAB–based framework for the computation of a large number of radiomic features and feature aggregation techniques in compliance with the IBSI guidelines.

METHOD:

- RОdiomiX is a series of computation cores that are implemented on the basis of the guidelines proposed by the IBSI. The RОdimoX software is capable of computing the following 11 different feature categories: Local-Intensity features, Intensity-Histogram features, Intensity- Based-Statistical features, Intensity-Volume-Histogram features, Gray-Level-Co-occurrence based features, Gray-Level-Run-Length based features, Gray-Level-Size-Zone based features, Gray-Level-Distance-Zone based features, Neighborhood-Grey-Tone-Difference based features, and Neighboring-Grey-Level-Dependence based features.
- RОdiomX software was validated using the following two different 3D digital phantoms: The IBSI and the HFHS gradient digital phantoms. Intraclass correlations (ICC with A-k method) for the degree of absolute agreement for the measurements that are averages of **k** independent measurements on randomly selected objects with confidence level of 0.95 were calculated and compared for each feature category.

RESULTS:

- Figure 1 and 2 show the HFHS gradient digital and IBSI phantoms. The HFHS phantom has four slices (32×32 voxels with voxel size of 2×2×2mm^3) with four corner-to-corner gradients (each rotated 90 degree clock-wise) with gray-level/intensities ranging from 1 to 64. The IBSI digital phantom consists of 5 × 4 × 4 (x, y, z) voxels with voxel size of 2.0 × 2.0 × 2.0 mm^3.
- The RОdiomX software was validated by the following two digital phantoms for different feature aggregation methods: (1)-HFHS gradient phantoms (Intraclass correlation, ICC>0.9, Rank: Excellent, see Table-1) and (2)-IBSI digital phantom (ICC>0.9, Rank: Excellent, see Table-1).
- Results of the RОdiomX software validation for the two digital phantoms imply that all the 2D and and 3D feature values computed for different aggregation methods are strongly in agreement (ICC>0.90, CL=0.95, Table 1) with the calculated and reported values by the two digital phantoms.
- RОdiomX computation cores facilitate contribution of creative algorithms and implementation of customized requirements by users around the world.



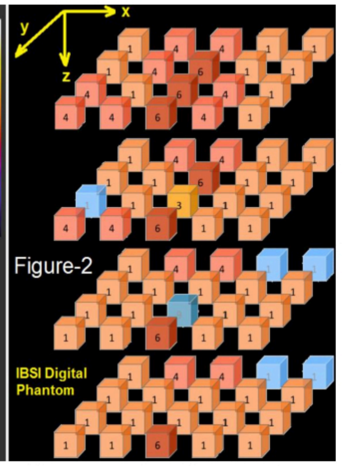


Figure-1: 3D view of the HFHS digital gradient phantom with 4 slices with 4 corner-to-corner gradients with two orthogonal directions for voxel intensities ranging from 1 to 64. **Figure-2:**IBSI Digital phantom

Feature Category	Aggregation Method	IBSI: ICC-RANK	HFHS: ICC-RANK
LI: 2 Features	3D-Volume (DHQ4)	0.997-Excellent	0.998-Excellent
IBS: 17 Features	3D-Volume (DHQ4)	1.000-Excellent	1.000-Excellent
IH: 22 Features	3D-Volume (DHQ4)	1.000-Excellent	1.000-Excellent
IVH: 7 Features	3D-Volume (DHQ4)	1.000-Excellent	1.000-Excellent
GLCM: 25 Features	2D-Averaged (BTW3)	1.000-Excellent	1.000-Excellent
GLCM: 25 Features	2D-Slice Merged (SUJT)	1.000-Excellent	1.000-Excellent
GLCM: 25 Features	2.5D-Dir. Merged (JJUI)	1.000-Excellent	1.000-Excellent
GLCM: 25 Features	2.5D-Merged (ZW7Z)	1.000-Excellent	1.000-Excellent
GLCM: 25 Features	3D-Averaged (ITBB)	1.000-Excellent	1.000-Excellent
GLCM: 25 Features	3D-Merged (IAZD)	1.000-Excellent	1.000-Excellent
GLRLM: 16 Features	2D-Averaged (BTW3)	1.000-Excellent	1.000-Excellent
GLRLM: 16 Features	2D-Slice Merged (SUJT)	1.000-Excellent	1.000-Excellent
GLRLM: 16 Features	2.5D-Dir. Merged (JJUI)	1.000-Excellent	1.000-Excellent
GLRLM: 16 Features	2.5D-Merged (ZW7Z)	1.000-Excellent	1.000-Excellent
GLRLM: 16 Features	3D-Averaged (ITBB)	1.000-Excellent	1.000-Excellent
GLRLM: 16 Features	3D-Merged (IAZD)	1.000-Excellent	1.000-Excellent
GLSZM: 16 Features	2D-Averaged (8QNN)	1.000-Excellent	1.000-Excellent
GLSZM: 16 Features	2.5D-Merged (62GR)	1.000-Excellent	1.000-Excellent
GLSZM: 16 Features	3D-Averaged (KOBO)	1.000-Excellent	1.000-Excellent
GLDZM: 16 Features	2D-Averaged (8QNN)	1.000-Excellent	1.000-Excellent
GLDZM: 16 Features	2.5D-Merged (62GR)	1.000-Excellent	1.000-Excellent
GLDZM: 16 Features	3D-Averaged (KOBO)	1.000-Excellent	1.000-Excellent
NGTDM: 5 Features	2D-Averaged (8QNN)	1.000-Excellent	1.000-Excellent
NGTDM: 5 Features	2.5D-Merged (62GR)	1.000-Excellent	1.000-Excellent
NGTDM: 5 Features	3D-Averaged (KOBO)	1.000-Excellent	1.000-Excellent
NGLDM: 17 Features	2D-Averaged (8QNN)	1.000-Excellent	1.000-Excellent
NGLDM: 17 Features	2.5D-Merged (62GR)	1.000-Excellent	1.000-Excellent
NGLDM: 17 Features	3D-Averaged (KOBO)	1.000-Excellent	1.000-Excellent

Table-1

- The HFHS gradient phantom can also be considered as an addition to existing digital phantoms. As a result, Given the structure and modularity of the software, users can extend its functionality by plugging in new algorithms for implementation of new radiomic feature computations and also perform radiomic analysis in batch processing mode for complicated tasks/projects.
- Also, developing the source codes within the MATLAB environment allows incorporation of different modules developed and shared by different research groups (MATLAB File-Exchange).

CONCLUSIONS:

The authors successfully developed a platform for computation of quantitative radiomic features. The image preprocessing and computational software cores were designed following the procedures specific by the IBSI. Benchmarking testing was in excellent agreement against the IBSI and HFHS-designed computational phantoms.

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