A Novel Computer-Aided Diagnostic System for Early Assessment of Hepatocellular Carcinoma

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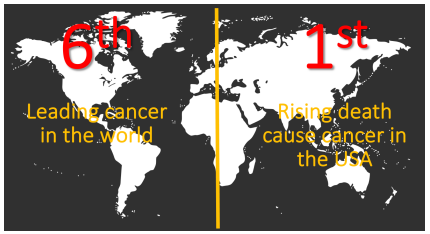
Abstract

- ***Purpose:*** Liver cancer is a major cause of morbidity and mortality in the world. The primary goals of this manuscript are the identification of novel imaging features (texture, functional, and shape), and development of a computer-aided diagnostic (CAD) system to accurately detect and grade liver tumors non-invasively.
- ***Methods:*** A total of 85 patients with liver tumors were enrolled in the study after consents were obtained. 34 patients had benign tumors, 17 patients had intermediate tumors, and 34 patients had hepatocellular carcinoma (HCC) malignant tumors. A multi-phase contrast-enhanced magnetic resonance imaging (CE-MRI) was collected to extract the imaging features. The proposed approach consists of three main steps. First, a pre-processing is applied to the CE-MRI scans to delineate the tumor lesions that will be used as a region of interest (ROI) across the four different phases of the CE-MRI. Second, a group of three features are modeled to provide a quantitative discrimination between the tumor lesions, namely: the tumor appearance that is modeled using a set of texture features, (namely; the first-order histogram features, second-order gray-level co-occurrence matrix (GLCM) features, and second-order gray-level run-length matrix (GLRLM) features), to capture any discrimination that may appear in the lesion texture; the spherical harmonics (SH) based shape features that have the ability to describe the shape complexity of the liver tumors; and the functional features that are based on the calculation of the wash-in/wash-out slopes to evaluate the intensity changes across different phases Finally, these features were integrated together to obtain the combined features to be fed to a machine learning classifier towards getting the final diagnostic decision.
- ***Results:*** Using the Random Forests classifier with a leave-one-out (LOSO) cross-validation, the developed CAD system achieved an 87.1% accuracy in distinguishing between malignant, intermediate and benign tumors (i.e., First stage classification). LR-1 lesions were classified from LR-2 benign lesions with 91.2% accuracy, while 85.3% accuracy was achieved differentiating between LR-4 and LR-5 malignant tumors (i.e., Second stage classification).

Problem and Research Motivation

Problem and Unmet Need



- Worldwide: 800,000 new cases and 700,000 new deaths.
- In the USA: 42,030 new cases and 31,780 deaths.
- At Global Averages: 1/5000 people is in danger of contracting HCC.

Current Diagnostic Tool, Gold Standard, and Limitations

For HCC, a radiological diagnosis (LI-RADS) provides high diagnostic performance and is considered as the Gold-Standard, which makes the medical organizations depend only on highly-experienced radiologists for HCC diagnosis.

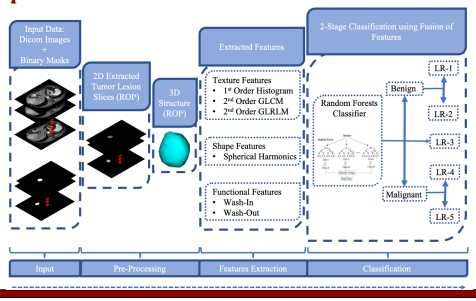
Research Motivation

There is an urgent need for an automated machine-learning based CAD system to identify HCC and its grade to provide the proper treatment plan.

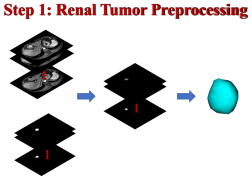
Data Collection

- A multi-phase contrast-enhanced magnetic resonance imaging (CE-MRI) was collected to extract the imaging features.
- A total of 85 patients with high risk of developing HCC without history of loco-regional treatment plan, (M = 61 and F = 24), provided their consent to participate in this study.
- 34 patients with benign tumors (LR-1 = 17 and LR-2 = 17), 17 with intermediate, and 34 with malignant tumors (LR-4 = 17 and LR-5 = 17)

The Proposed Framework

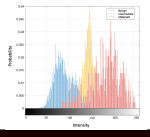


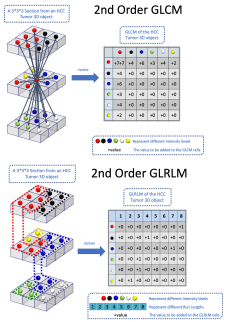
Step 1: Renal Tumor Preprocessing



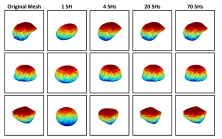
Step 2: Features extraction

Texture Features

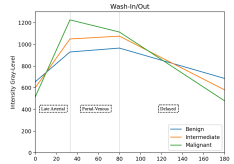




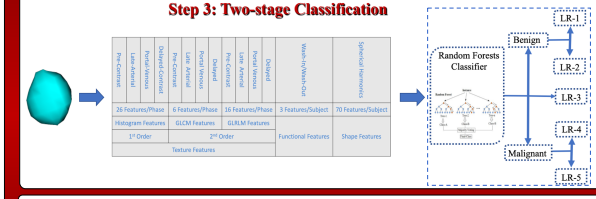
Shape Features (70 SHs)



Functional Features (Wash In/Out)



Step 3: Two-stage Classification



Experimental Diagnostic Results

1st Stage

Approach	Accuracy	AUROC (+ve Class)			Correct Instances		
		B	LR3	M	B/34	LR3/17	M/34
LOSO	87.1%	0.95	0.92	0.91	33	11	30
10-Fold	85.9%	0.93	0.84	0.89	31	12	30
5-Fold	81.2%	0.88	0.89	0.87	32	9	28

2nd Stage

Approach	Accuracy	AUROC	Correct Instances	
LR1 vs. LR2			LR1/17	LR2/17
LOSO	91.2%	0.95	14	17
10-Fold	88.2%	0.92	13	17
5-Fold	85.3%	0.90	12	17
LR4 vs. LR5			LR4/17	LR5/17
LOSO	85.3%	0.88	16	13
10-Fold	82.4%	0.83	15	13
5-Fold	82.4%	0.83	15	13

Conclusions and Future Work

- In order to provide the proper management plan, the developed CAD system demonstrated high classification accuracy of **87.1** in differentiating between malignant, intermediate, and benign tumors; a high classification accuracy of **91.2%** in distinguishing LR-1 from LR-2 benign tumors; and 85.3% to differentiate between LR-4 and LR-5 malignant tumors.
- The integration process of accurate shape features with functional features and first and second order texture features was efficient enough to enhance the final diagnostic performance.
- The CAD system will be optimized by training and validating on a larger balanced patient cohort using CE-MRI. Furthermore, we are collecting new liver tumors with different diagnosis including LR-M to investigate the abilities of the CAD system in a bigger classification problem.

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