Paper ID:1407

EXPLAINABLE PREDICTION OF RENAL CELL CARCINOMA FROM CONTRAST-ENHANCED CT IMAGES USING DEEP CONVOLUTIONAL TRANSFER LEARNING AND THE SHAPLEY ADDITIVE EXPLANATIONS APPROACH

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- Renal cell carcinoma (RCC) is the most common type of malignant kidney cancer.

- The visual identification method relies heavily on the experience and state of clinicians.

➢ It has become increasingly important to automatically and efficiently diagnose RCC.

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Current state-of-the-art methods：

- The first class is conventional machine learning methods. Logistic regression (LR), kernel machines, tree-based methods, and ensemble methods (boosting, bagging and random forest).
- The second class is deep learning. These methods usually append one prediction branch to the final output of a convolutional neural network (CNN) framework.

➢ **However,** (1) these machine learning models remain mostly black boxes, and (2) these approaches lack multiscale feature extraction and fusion steps for better performance.

Challenges：

- The first aspect is limited clinical data.
- The second aspect is the inconsistent number of region of interest (ROI) segmentations.
- The third aspect is trust in the model and clinical utility evaluation.

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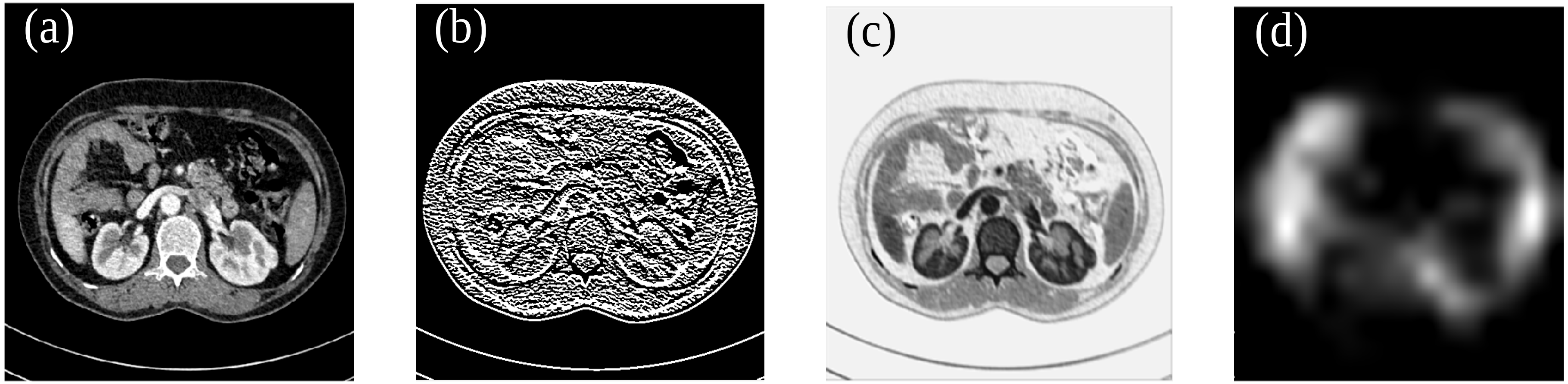

Fig. 1. Image comparison. (a) CT image. (b) Texture image. (c) Feature map from the shallow layer. (d) Feature map from the deep layer.

Motivation:

- We focus on deep convolutional transfer learning and the SHAP approach.
- Multiscale feature extraction is performed to obtain comprehensive features (texture features, deep features, and shallow features).
- A decision curve analysis (DCA) module is performed for the clinical utility evaluation.

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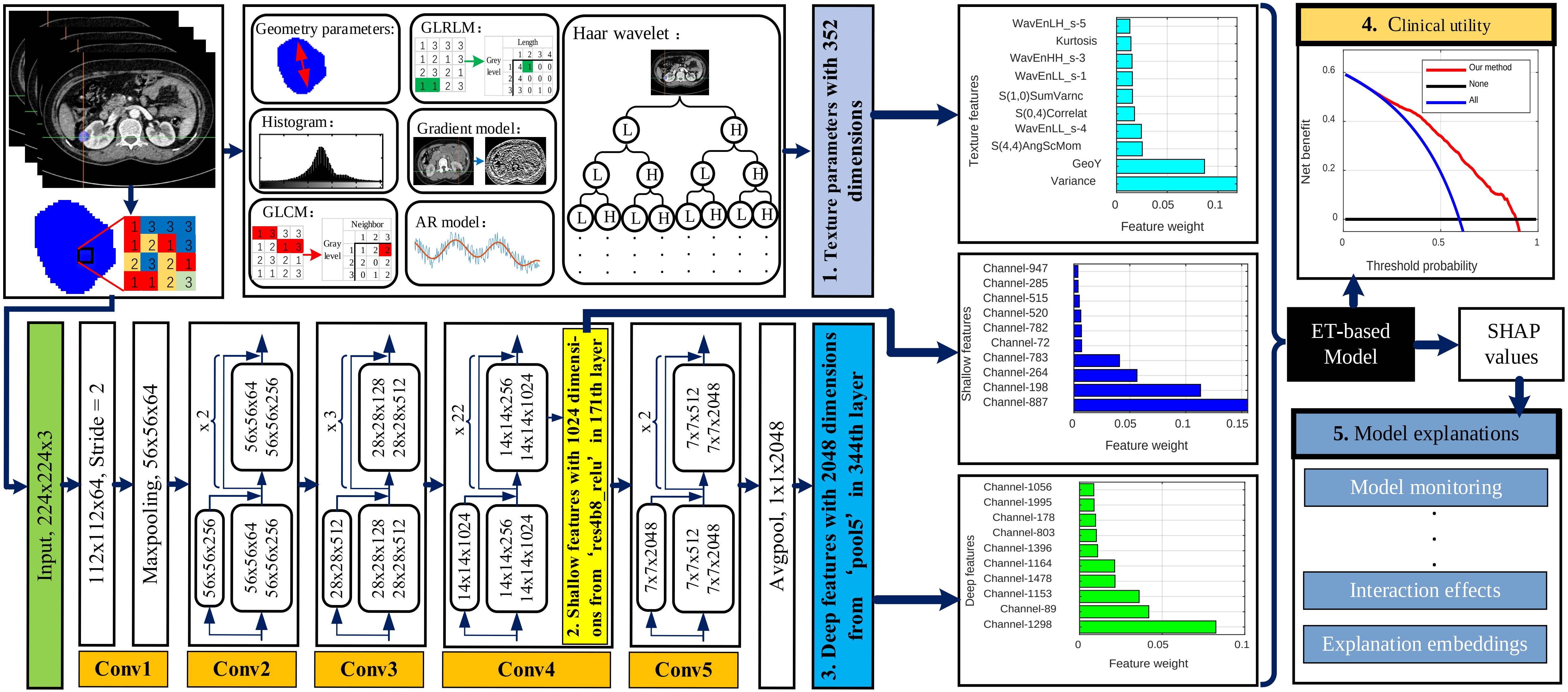

Fig. 1. Flowchart of the proposed method.

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A. Image Preprocessing

- Preprocessing pipeline: (1) tumor stripping, (2) standardization, and (3) sampling.

B. Feature Engineering

- (1) Texture parameters with 352 dimensions; (2) Shallow features with 1024 dimensions from the res4b8_relu block in the 171st layer of ResNet-101; (3) Deep features with 2048 dimensions from the pool5 block in the 344th layer of ResNet-101. All features are evaluated by the mRMR method, and the high-importance features are selected.

C. Classification Models

- We build extra trees classifier (ET). The 30 best selected features are finally supplied to the ET model for final classification.

D. Model Explanations

- Shapley additive explanations (SHAP) is applied in this study to explain the output of machine learning model.

E. Clinical Utility Evaluation

- Decision curve analysis (DCA) provides a framework to evaluate the predictive models that incorporates the balancing of risks and benefits of treatment.

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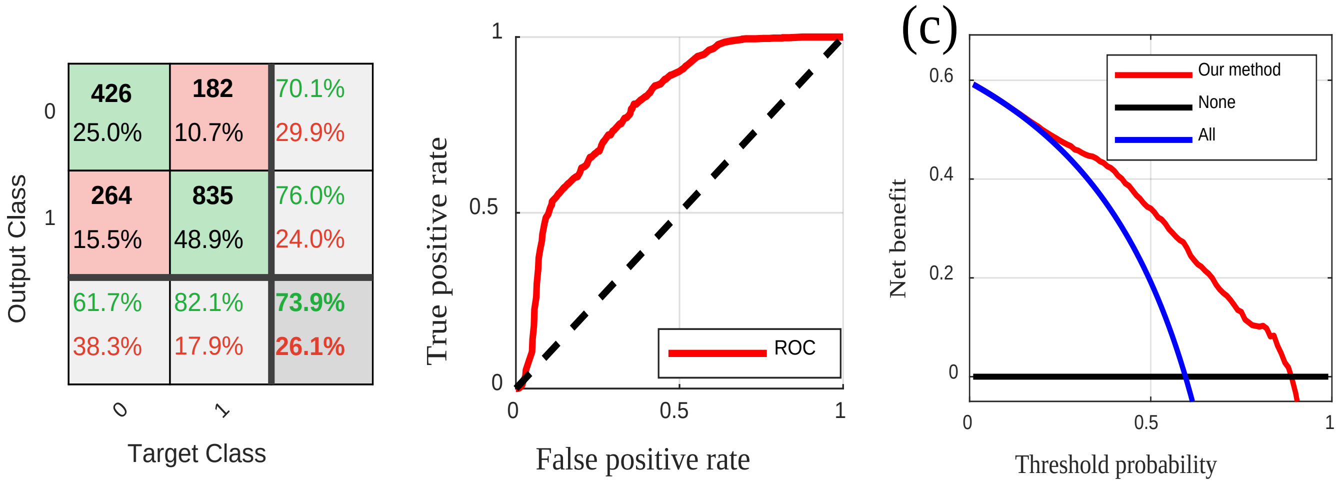
A. Data Processing and Experimental Results:

This study is a retrospective study approved by the institutional ethics review board at Hunan cancer hospital (Changsha, China).

Table 1. Characteristics and groups of patients.

Parameters	Benign	RCC
Patient & image number	29 & 2255	40 & 3105
Age (mean ± SD)	51.8 ± 9.06	49.2±10.6
Gender (male/femal)	7/22	18/22
Training set (p.no & i.no)	20 & 1,565	28 & 2,088
Testing set (p.no & i.no)	9 & 690	12 & 1,017

SD: standard deviation, p.no: the number of patient, i.no: the number of image.



The experimental results obtained by our model.
(a) Confusion matrix. (b) ROC curve. (c) Decision curve.

- Each CT image were resized to 224x224x3, and then three-stage feature extractions were performed.
- Our model achieves an accuracy of 73.87% and an area under the curve (AUC) of 0.8030.

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B. Comparison with State-of-the-Art Methods：

Table 2. Performance comparison of some pretrained deep models with fine-tuned parameters.

Network	Depth	Layers	Image input size	Training loss	Training accuracy	Testing loss	Testing accuracy
DenseNet-201	201	709	224 by 224	0.0456	97.5890%	2.1841	54.4206%
GoogleNet	22	144	224 by 224	0.0627	97.0411%	1.5518	60.5647%
Inception-v3	48	316	299 by 299	0.0356	97.3973%	2.1221	60.0211%
ResNet-101	101	347	224 by 224	0.0368	97.3973%	2.0440	**64.9889%**
ShuffleNet	50	172	224 by 224	0.0368	97.4795%	3.0737	53.3216%
Xception	71	170	299 by 299	0.0375	97.4795%	1.5424	56.8155%

Table 3. Performance comparison of ResNet-101 with state-of-the-art ensemble tree methods.

ResNet-101 + Trees	Training process		Testing process	
	Accuracy	AUC	Accuracy	AUC
DT	**0.9989**	**0.999998**	0.6608	0.6368
RF	0.9970	0.999974	0.6210	0.6810
GBC	0.9808	0.999097	0.6520	0.7346
XGBoost	0.9795	0.998949	0.6661	0.7764
CatBoost	**0.9989**	**0.999998**	0.6514	0.7806
Our method	**0.9989**	**0.999998**	**0.7387**	**0.8030**

- ResNet-101 yields better results than state-of-the-art pretrained CNN classification methods.
- It is obvious that the model built by ET classifier exhibits decent discriminating abilities.

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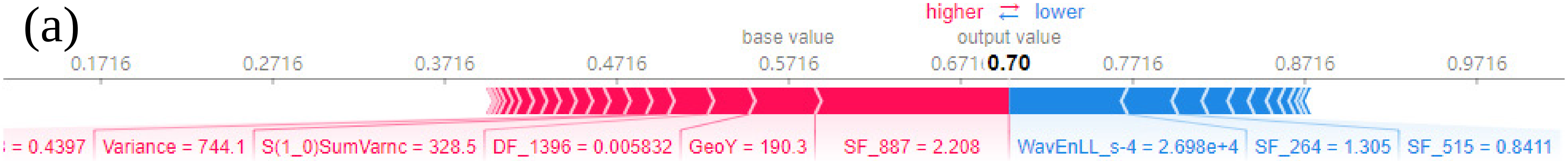
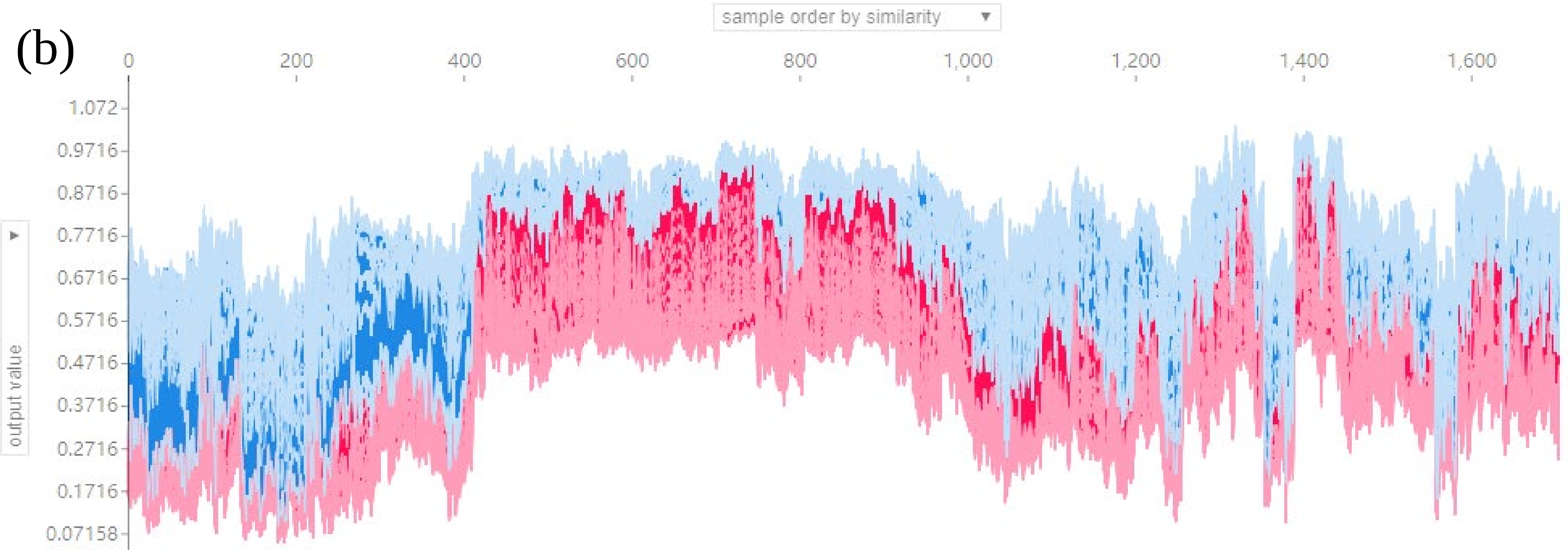
C. Model Explanation:

(a)



(b)



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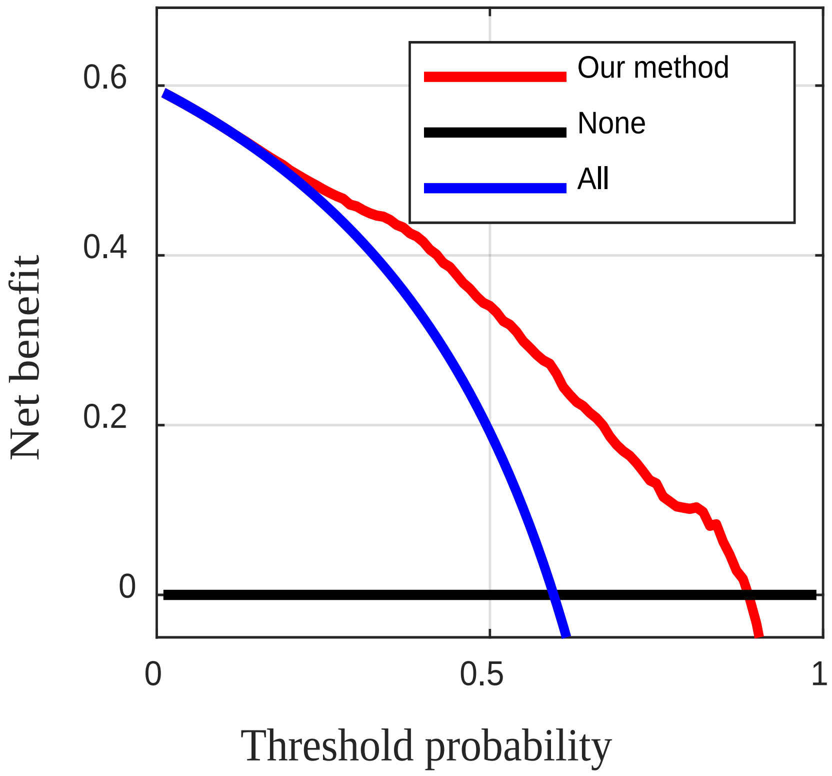
D. Clinical Utility Evaluation:



- If the threshold probability of a patient or doctor is approximately 20%, using our model to predict RCC adds more benefit than either the treat-all-patients scheme or the treat-none scheme.

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Contribution：

- A multiscale feature extraction module;
- An attribute optimization module based on mRMR method;
- Appending a SHAP module to the framework to automatically and efficiently interpret the prediction of the model;
- A decision curve analysis (DCA) module is performed for the clinical utility evaluation.

➢ Our ET model achieves higher accuracies than the state-of-the-art deep CNN models and other ensemble tree methods.

Limitations:

➢ In future work, we will test the proposed explainable model with more labeled clinical datasets to expand the application range and improve the robustness and accuracy of the model.

➢ The authors are also working to explore the utilization of 3D CT information for providing further insights into the prediction mechanism of RCC.

THANKS FOR ALL