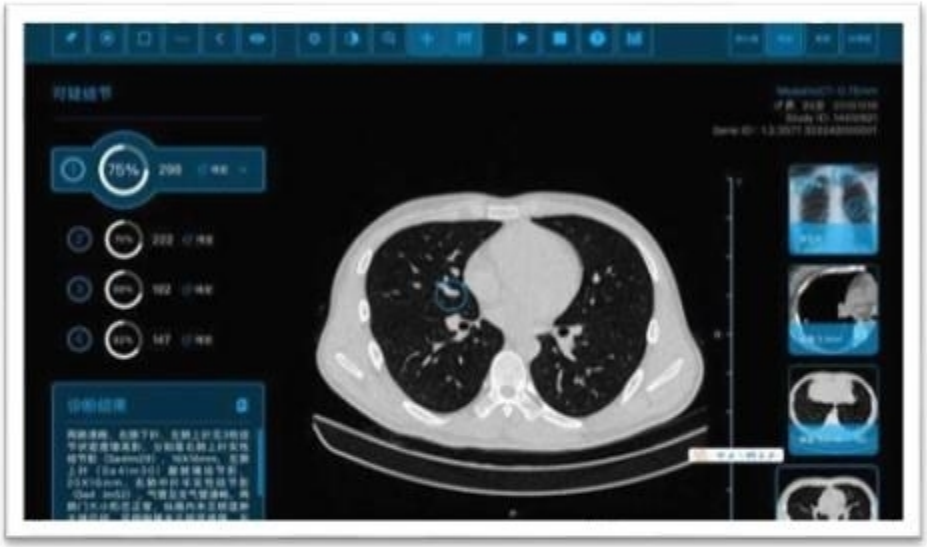
人工智能（AI）与肺结节

人工智能

- 人工智能是研究使计算机来模拟人的某些思维过程和智能行为（如学习、推理、思考、规划等）的学科
- 主要包括计算机实现智能的原理、制造类似于人脑智能的计算机，使计算机能实现更高层次的应用
- 人工智能将涉及到计算机科学、心理学、哲学和语言学等学科

AI与肺结节诊断



结节识别

结节分割

特征提取

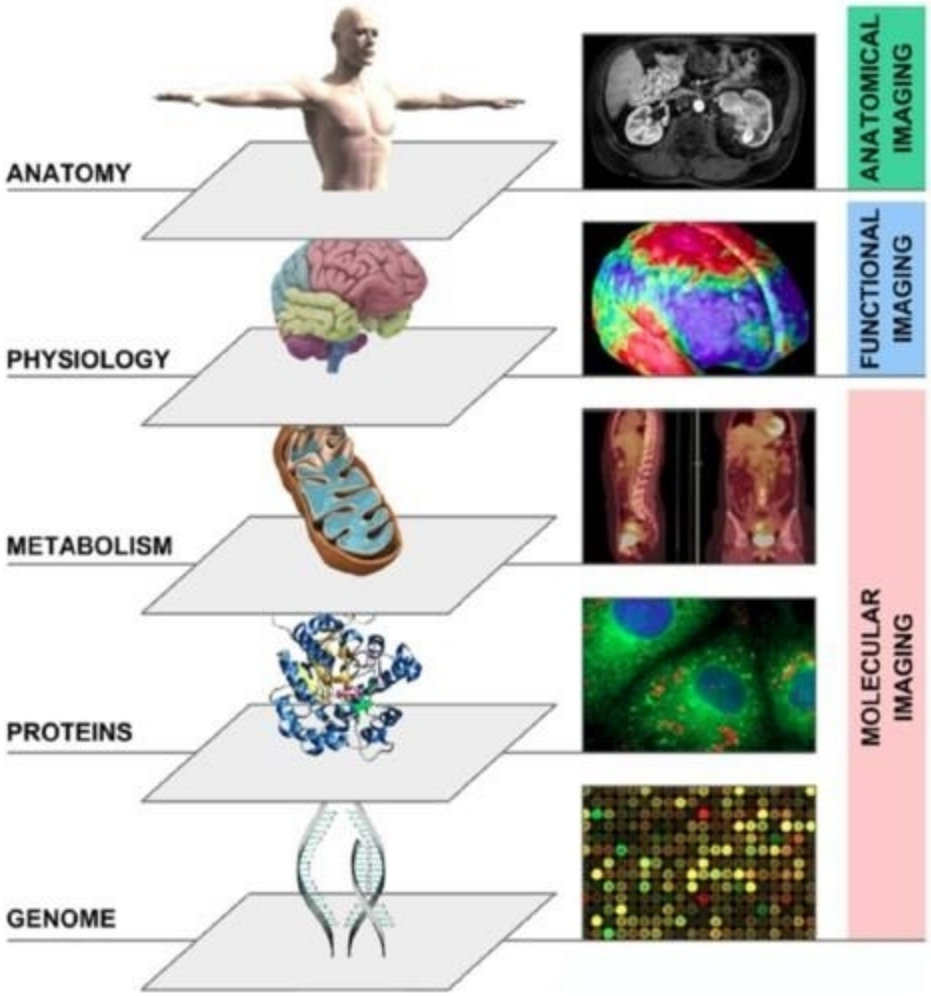
数据分析

模型建立

辅助诊断

指导策略

影像组学



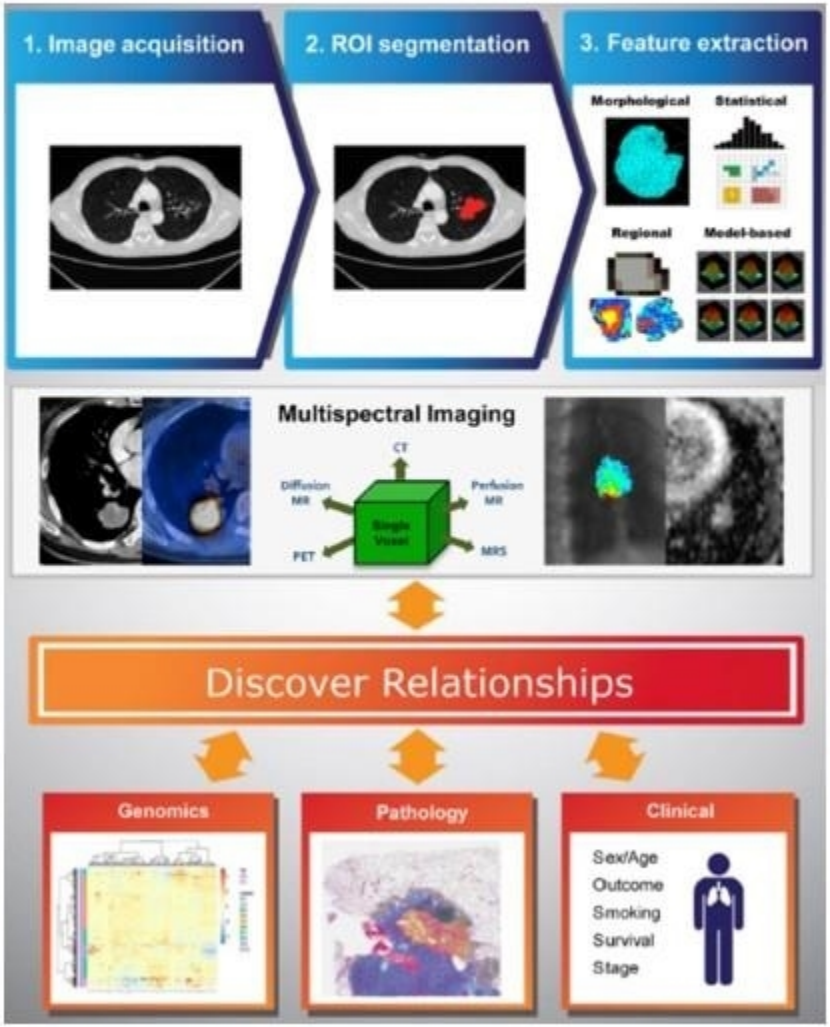
与潜在的基因表达类型相关联

揭示肿瘤预测性的信号

捕获肿瘤内在的异质性

Eur J Cancer. 2012, 48(4): 441–446

主要技术方案



Eur J Radiol. 2017 Jan;86:297-307.

人工智能用于影像组学

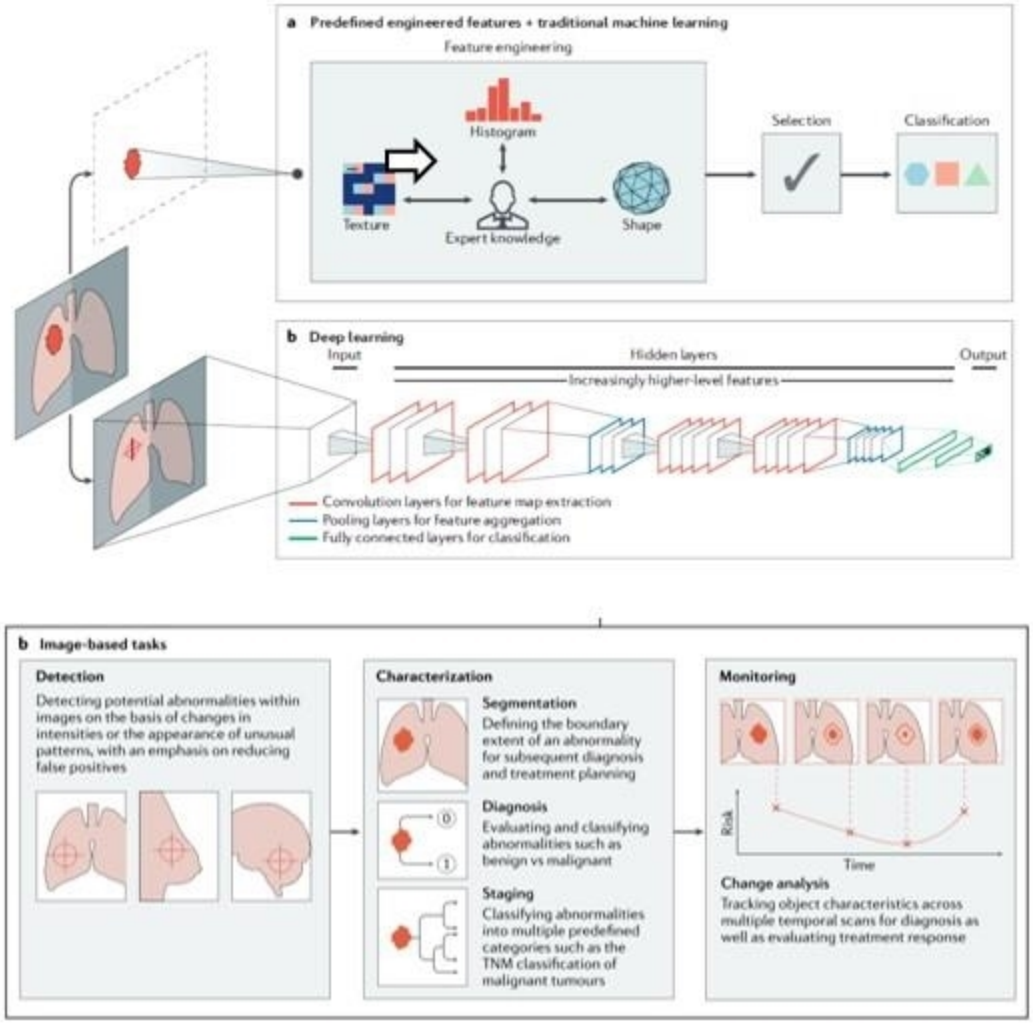
结节识别

图像分割

特征提取

模型建立

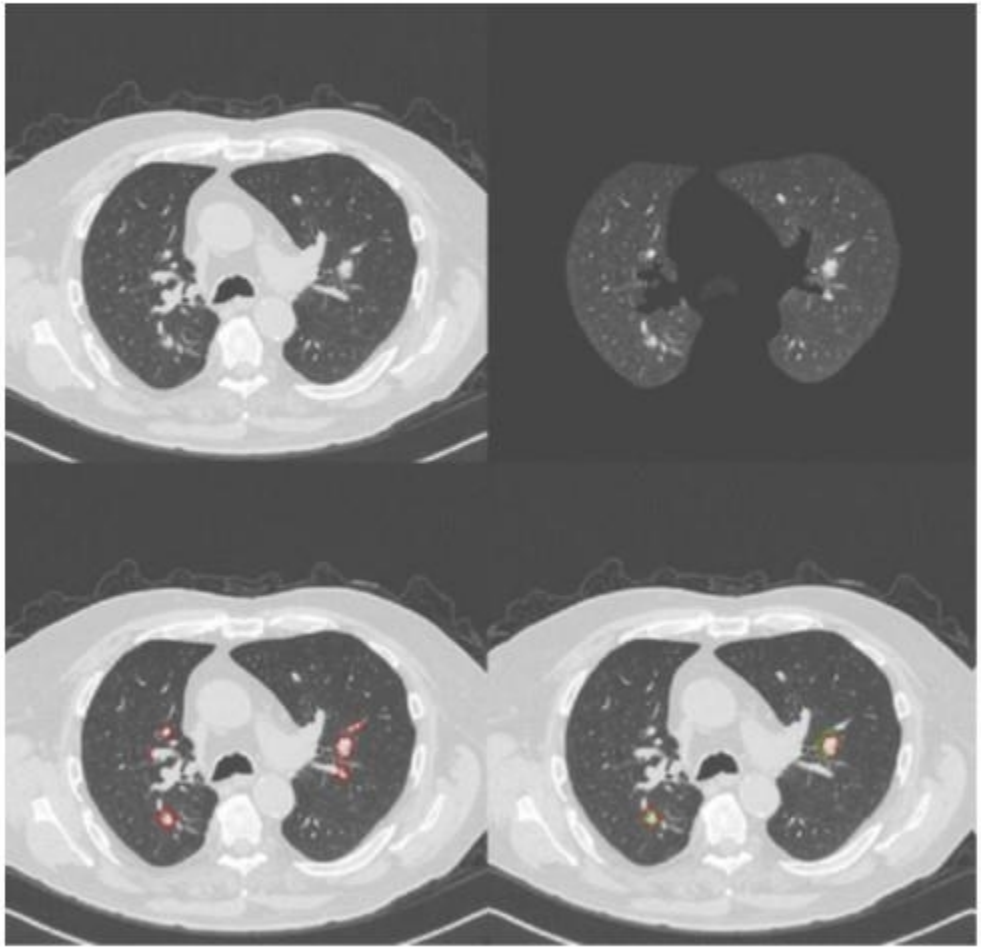
随访监测



Nature Reviews Cancer. 2018;18:500-10.

结节识别

- 历史悠久
- 诸多算法
- 敏感性高
- 假阳性相对较高



人工智能用于肺结节识别

Nodule detection

Rank	Team	Date	Score
1	PAtech (PA_tech)	2 January 2018	0.951
2	JianPeiCAD (weiyixie)	22 December 2017	0.950
3	LUNA16FONOVACAD (zxp774747)	28 November 2017	0.947
4	iFLYTEK-MIG (yinbaocai)	17 August 2017	0.941
5	zhongliu_xie (zhongliu.xie)	29 September 2017	0.922
6	iDST-VC (chenjx1005)	13 July 2017	0.897
7	qfpxfd (qfpxfd)	27 May 2017	0.891
8	CASED (CASED)	15 June 2017	0.887
9	3DCNN_NDET (lishaxue3)	22 June 2017	0.882
10	Aidence (mjharte)	7 June 2017	0.871

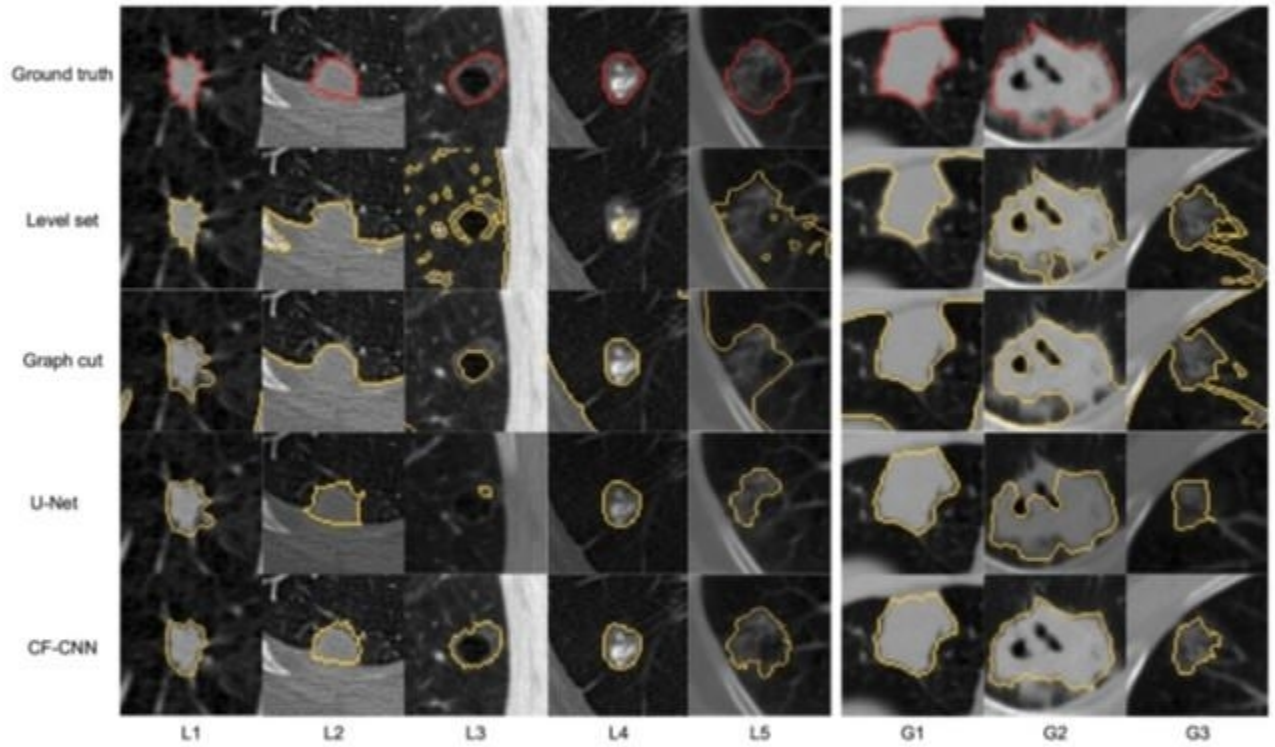
False positive reduction

Rank	Team	Date	Score
1	PATech (PA_tech)	20 December 2017	0.968
2	LUNA16FONOVACAD (zxp774747)	15 September 2017	0.966
3	IHPC_zkj (zkj)	24 July 2017	0.965
4	MILAB_ConcatCAD (bckim)	21 August 2017	0.940
5	JianPeiCAD (weiyixie)	21 July 2017	0.916
6	qfpxfd (pku.hzq)	26 May 2017	0.913
7	GIVECAD (ZJUGIVE)	17 May 2017	0.912
8	CUMedVis (QiDou)	15 May 2016	0.908
9	MILAB_ResCAD (bckim)	21 July 2017	0.889
10	JianPeiCAD (weiyixie)	24 December 2016	0.889

- 国际权威肺结节检测大赛（LUNA16）的最新排名
- 中国人工智能团队PAtech高居榜首
- 结节检出率95.1%，假阳性率减少96.8%

https://luna16.grand-challenge.org/results/

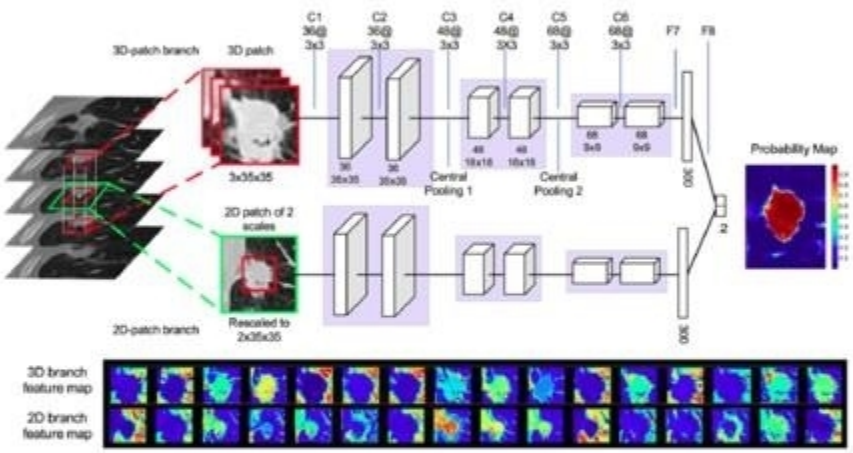
结节分割

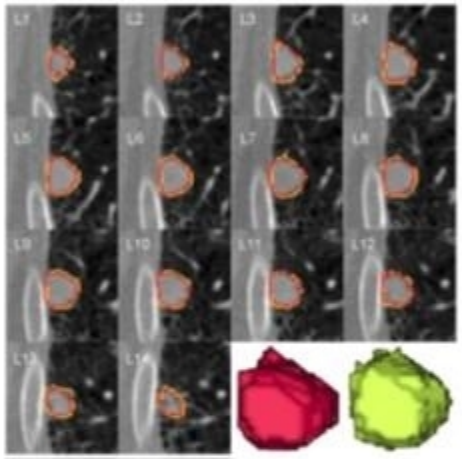


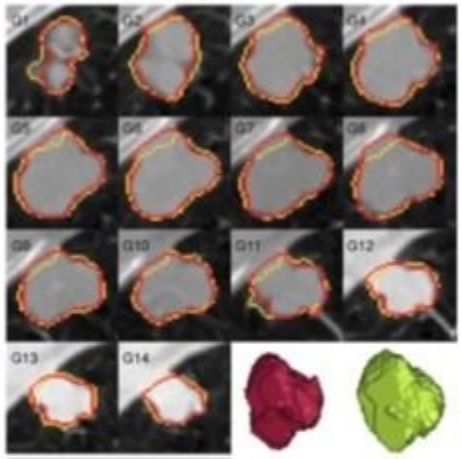
- 手动分割、自动分割、联合

人工智能用于结节分割

Central Focused Convolutional Neural Networks (CF-CNN)







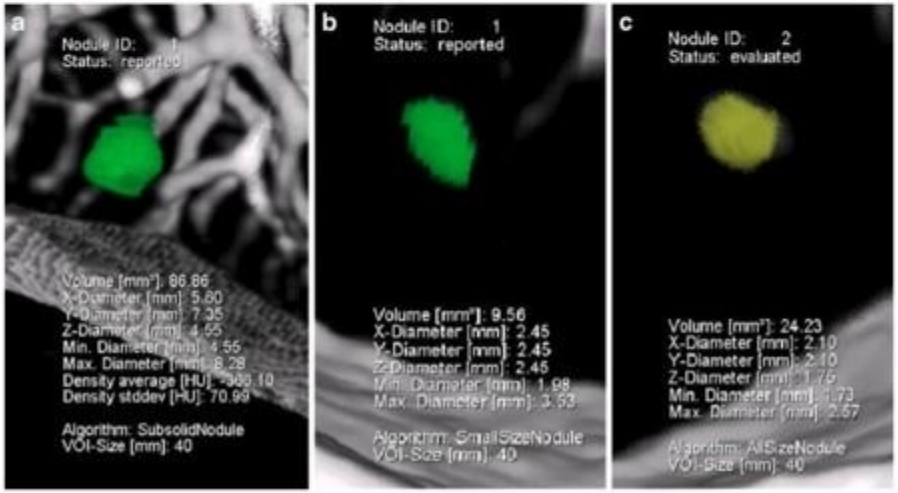
LIDC Set	DSC (%)	ASD (mm)	SEN (%)	PPV (%)
Level Set	60.63± 17.39	0.48± 0.25	64.38± 22.75	71.03± 24.35
Graph Cut	68.90± 16.03	0.48± 0.30	80.81± 15.25	65.09± 22.42
U-Net	79.50± 13.95	0.24± 0.23	86.81± 18.43	78.18± 16.13
3-D-Patch Branch	79.20± 11.88	0.21± 0.17	90.93± 14.72	72.91± 13.73
2-D-Patch Branch	80.47± 11.23	0.18± 0.15	91.36± 14.40	74.64± 13.16
CF-CNN-MP	80.39± 11.90	0.18± 0.15	91.33± 14.88	74.52± 13.54
CF-CNN	82.15± 10.76	0.17± 0.23	92.75± 12.83	75.84± 13.14

观察者差异率
1.98%

Med Image Anal. 2017 Aug; 40: 172–183.

人工智能用于结节分割

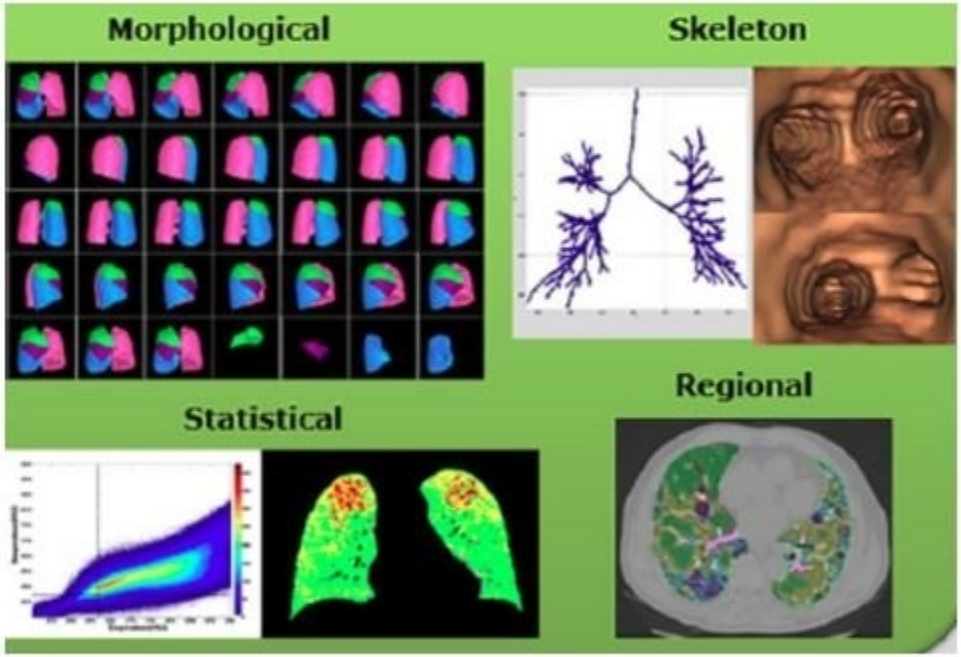
	Algorithm of 1st reader	Algorithm of 2nd reader	No. of nodule readings, (%)	Volume of nodules, Mean (range) mm^3	Difference between readers (1st – 2nd) Mean (SD) Percent of minimal reading	Range	No difference in volume	Difference in volume >25%
Same algorithms	Small size	Small size	252 (65)	160 (7–2,088)	−1 (11)	−65 to 48	58%	4%
	All sizes	All sizes	36 (9)	1,056 (146–3,486)	1 (6)	−14 to 31	22%	3%
	Subsolid	Subsolid	23 (6)	392 (51–1,296)	−1 (3)	−5 to 8	4%	0%
	Total		311 (80)	281 (7–3,486)	0 (10)	−65 to 48	50%	4%
Different algorithms	Small size	All sizes	35 (9)	255 (6–995)	−100 (154)	−890 to −6	0%	77%
	All sizes	Small size	34(8)	304 (9–1,780)	77 (74)	14–406	0%	82%
	Small/All sizes	Subsolid	11 (3)	249 (5–2,107)	−1,428 (1,368)	−4,379 to −196	0%	100%
	Subsolid	Small/All sizes	0 (0)	–	–	–	–	–
	Total		80 (20)	275 (5-2,107)	−207 (705)	−4,379 to 406	0%	83%

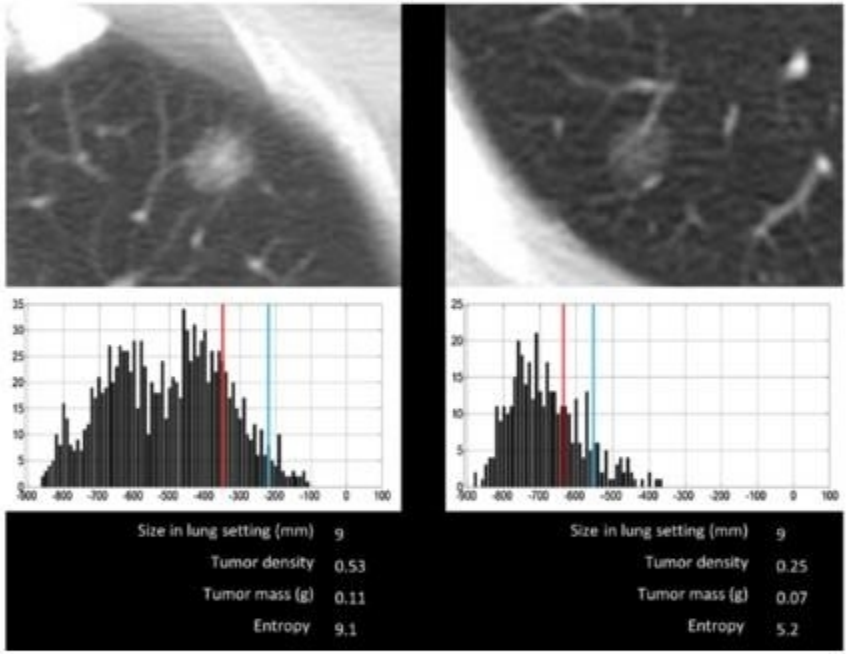


- 同一软件采用不同的结节分割算法，容积测量差异>25%的结节比例高达83%

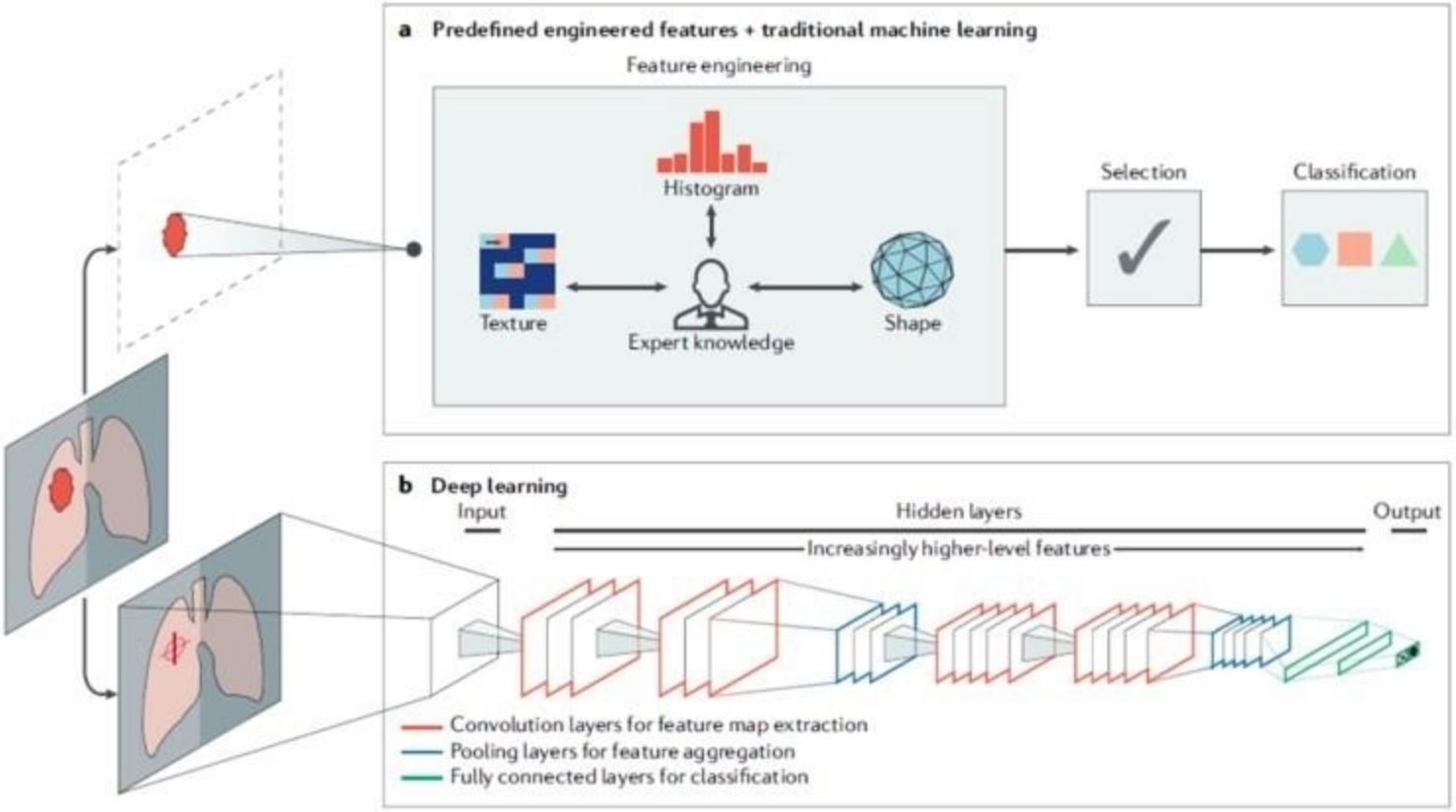
Eur Radiol. 2010, 20(8): 1878–1885.

特征提取



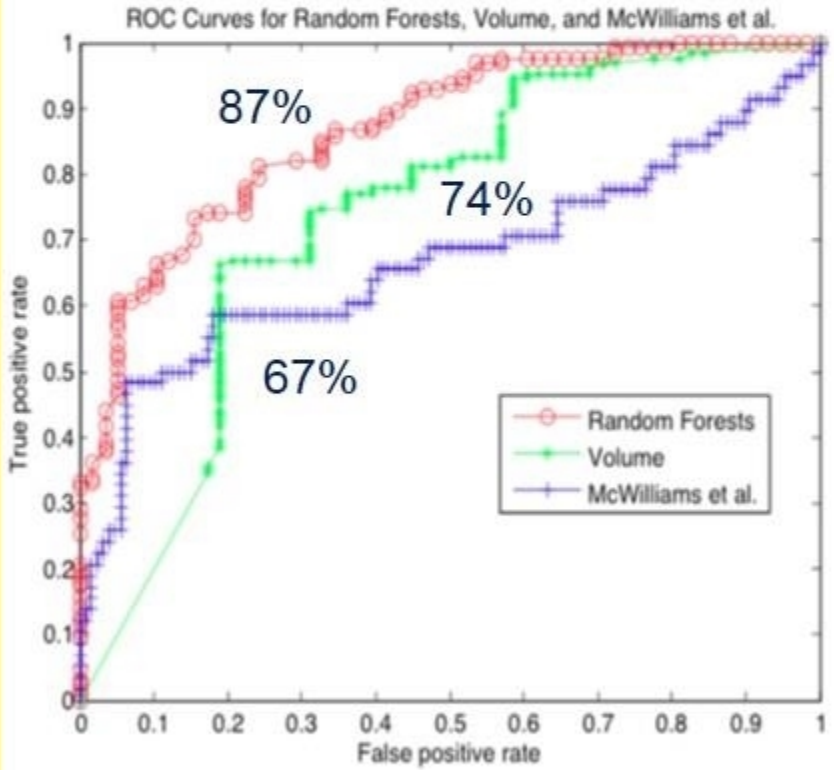


数据分析和模型建立


a Predefined engineered features + traditional machine learning
Feature engineering
Histogram
Texture
Expert knowledge
Shape
Selection
Classification
b Deep learning
Input
Hidden layers
Output
Increasingly higher-level features
Convolution layers for feature map extraction
Pooling layers for feature aggregation
Fully connected layers for classification

结节良恶性鉴别

- 研究对象：NLST筛查患者数据
  - Cohort1：肺癌104，良性结节208
  - Cohort2：肺癌92，良性结节196
- 结节分割：single-click ensemble segmentation approach
- 特征提取：219个特征中筛选23个，5种算法比较，random forest classifier
- 模型建立：SVM
- 准确性：第一年80%，第二年89%



J Thorac Oncol. 2016, 11(12): 2120–2128.

结节良恶性鉴别

- 研究对象：NLST筛查患者数据
  - 训练组：恶性结节200，良性结节200
  - 测试组：恶性结节122，良性结节71
- 结节分割：Toboggan based growing automatic segmentation approach
- 特征提取：150个特征中筛选15个，random forest classifier
- 模型建立：SVM

Subset	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
Training set	82.5(165/200)	89.5(179/200)	88.7(165/186)	83.6(179/214)	86.0(344/400)
Testing set	74.6%(91/122)	78.9(56/71)	85.8(91/106)	66.7(58/87)	76.1(147/193)
Overall	79.5(256/322)	86.7(235/271)	87.7(256/292)	78.7(237/301)	82.7(491/593)

Conf Proc IEEE Eng Med Biol Soc. 2016:1272-1275.

结节良恶性鉴别

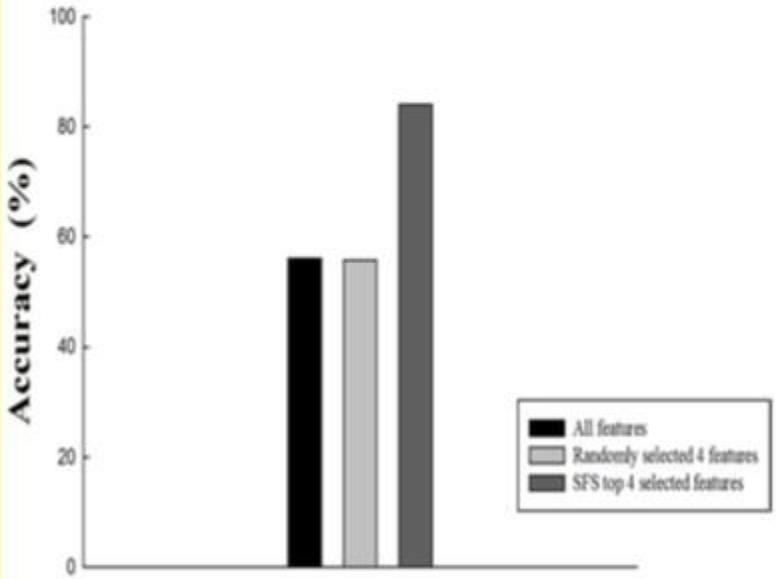
- 研究对象：NLST筛查患者数据
  - 恶性结节41，良性结节31
- 结节分割：Insight Segmentation and Registration Toolkit
- 特征提取：103个特征中筛选14个，hierarchical clustering method
- 模型建立：SVM-LASSO

Prediction Model	Sensitivity	Specificity	Accuracy	AUC	# of Features
Lung-RADS	80.5%	61.3%	72.2%	0.77	4
SVM-LASSO	87.2±1.4%	81.2±3.2%	84.6±1.5%	0.89±0.01	2

Med Phys. 2018, 45(4):1537-1549

结节良恶性鉴别

- 研究对象：NLST筛查患者数据
  - 恶性结节40，良性结节32
- 结节分割：人工分割
- 特征提取：750个特征中筛选4个，Wilcoxon rank sum test+SFS
- 模型建立：SVM-LOO-CV
- 敏感性：92.85%
- 特异性：72.73%
- 准确性84%



PLoS ONE. 2018, 13(2): e0192002