Joint Weber-based Rotation Invariant Uniform Local Ternary Pattern For Classification Of Pulmonary Emphysema In CT Images

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ICIP 2017 Sep. 18, 2017 - Sep. 20, 2017

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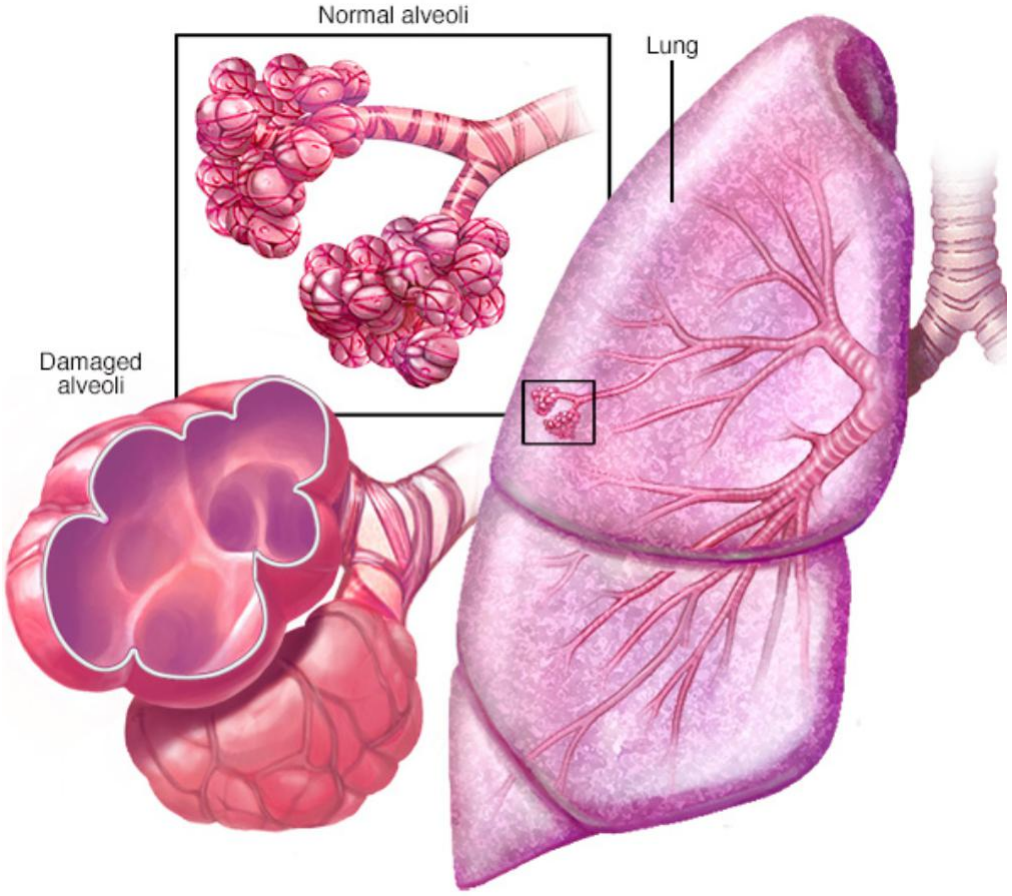
Introduction Background

What is emphysema?

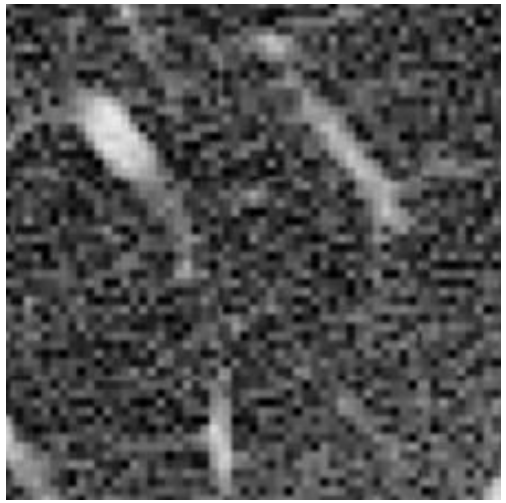


- Chronic lung disease
- Excessive expansion of the alveoli(air sacs in the lungs)
- Harder to breathe

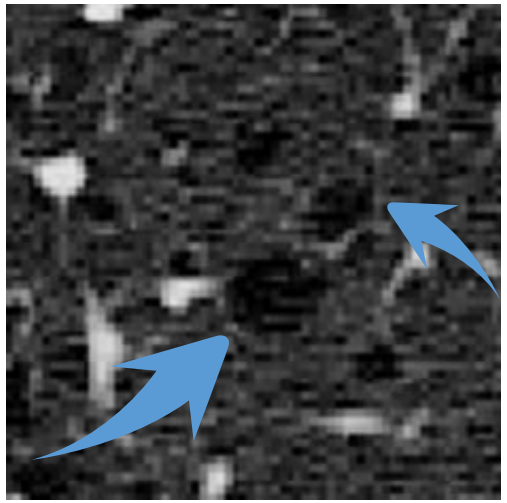
Image source: http://www.mayoclinic.org

Introduction Background

What does emphysema look like in CT images?

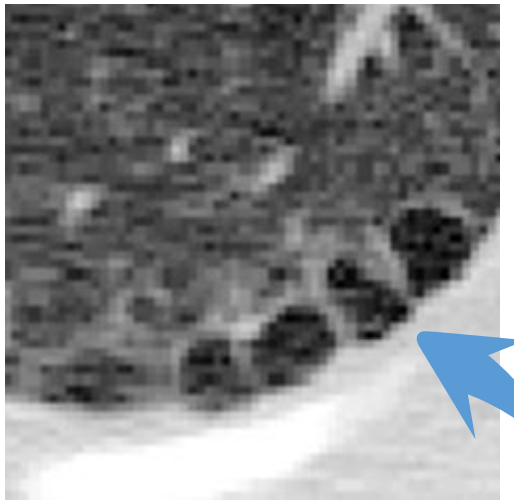


Normal tissue(NT)



Centrilobular emphysema (CLE)

Panlobular emphysema (PLE)



Paraseptal emphysema (PSE)

Introduction Motivation

- The main component of chronic obstructive pulmonary disease(COPD).
- The world's growing health problem.
- One of the world's most serious diseases.

Detection and quantification of emphysema is important

In clinical practice, to evaluate the severity of emphysema is based on the subjective judgment of radiologist. (**Not accurate,time-consuming**)
→ Design a powerful feature for the automatic quantification of emphysema. (**Accurate,effective**)

Since the **texture** of lung tissue is affected by the type of emphysema, **texture analysis** can be applied to quantitative analysis of different subtypes of emphysema

Introduction Related work

Rotation invariant local binary patterns (RILBP) [1]

[1] Sorensen, Lauge, Saher B. Shaker, and Marleen De Bruijne."Quantitative analysis of pulmonary emphysema using local binary patterns." IEEE transactions on medical imaging 29.2 (2010): 559-569.

Texton-based feature (Bag of visual words,BOVW) [2]

[2] Gangeh, Mehrdad J., et al. "A texton-based approach for the classification of lung parenchyma in CT images". International Conference on Medical Image Computing and Computer-Assisted Intervention. Springer Berlin Heidelberg, 2010.

Introduction Contributions

Joint Weber-based Rotation Invariant Uniform Local Ternary Pattern

For Classification Of Pulmonary Emphysema In CT Images

RIULTP

Extend the local ternary pattern (LTP) with the same principle as rotation invariant uniform local binary pattern (RIUL**B**P) [3], and present the **rotation invariant uniform local ternary pattern (RIULTP).**

WRIULTP

Our proposed **Weber-based RIULTP (WRIULTP)** depends not only on the absolute value of the stimulus but also on the relative intensity of stimulus

JWRIULTP

By integrating the upper pattern and the lower pattern of the WRIULTP, we further present the **joint Weber-based rotation invariant uniform local ternary pattern (JWRIULTP).**

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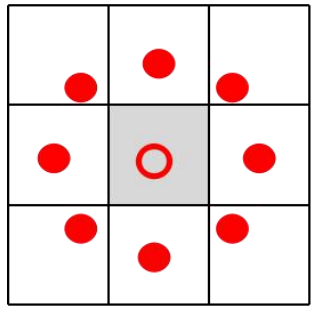
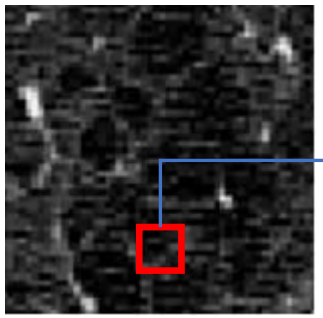
Methods Rotation invariant uniform LTP (RIULTP)

(R=1,P=8)





100	90	40
212	100	12
200	98	103

Raw Intensity

t =5

Threshold Function

$$T_U(I(x_p)-I(x))=\begin{cases}1 & \text{if } I(x_p)-I(x)\geq t\\ 0 & \text{if } I(x_p)-I(x)<t\end{cases}$$

$$LTPU^{riu2}(x;R,P)=\begin{cases}\sum_{p=0}^{P-1}T_U(I(x_p)-I(x)) & \text{if } U_U(LTP(x;R,P))\leq 2\\ P+1 & \text{otherwise}\end{cases}$$

0	0	0
1		0
1	0	0

Upper Pattern

$U_U(LTP(x;R,P))\leq 2$

Calculate the number of spatial transitions(bitwise 0/1 changes)

	2	

Upper Pattern

Lower Pattern

0	1	1
0		1
0	0	0

Lower Pattern

$U_L(LTP(x;R,P))\leq 2$

Calculate the number of spatial transitions(bitwise 0/1 changes)

	3	

Threshold Function

$$T_L(I(x_p)-I(x))=\begin{cases}1 & \text{if } I(x_p)-I(x)\leq -t\\ 0 & \text{if } I(x_p)-I(x)>-t\end{cases}$$

$$LTPL^{riu2}(x;R,P)=\begin{cases}\sum_{p=0}^{P-1}T_L(I(x_p)-I(x)) & \text{if } U_L(LTP(x;R,P))\leq 2\\ P+1 & \text{otherwise}\end{cases}$$

$I(x)$: Intensity of center pixel

$I(x_p)$: Intensity of surrounding pixel

t : Threshold

R : Radius

P : The number of neighbors

Methods Weber-based RIULTP (WRIULTP)

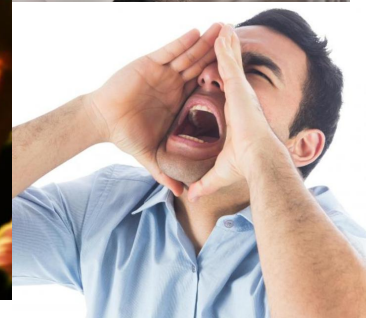
Weber's law (The psychological law proposed by Weber)

$$\frac{\Delta R}{R} = k(\text{constant})$$

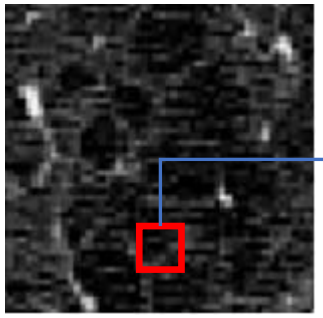
R: initial stimuli

△R: the change in stimuli

k: constant



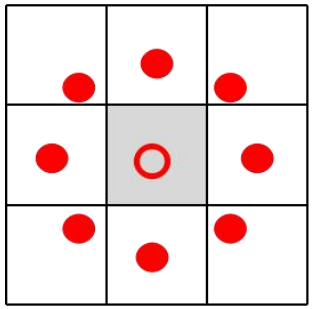
Methods Rotation-based Robust LTP for RIULTP (RIULTP)



100	90	40
212	100	12
200	98	103

Raw Intensity

(R=1,P=8)



$I(x)$: Intensity of center pixel

$I(x_p)$: Intensity of surrounding pixel

t : Threshold

R : Radius

P : The number of neighbors

Threshold Function

$$T_W\left(\frac{I(x_p)-I(x)}{I(x)}\right)=\begin{cases}1 & \text{if } \frac{I(x_p)-I(x)}{I(x)} \geq t \\ 0 & \text{if } \frac{I(x_p)-I(x)}{I(x)} < t\end{cases}$$

$$WLTPU^{riu2}(x;R,P)=\begin{cases}\sum_{p=0}^{P-1} T_U\left(\frac{I(x_p)-I(x)}{I(x)}\right) & \text{if } U_U(LTP(x;R,P)) \leq 2 \\ P+1 & \text{otherwise}\end{cases}$$

t = 0.1

0	0	0
1		0
1	0	0

Upper Pattern

$U_U(LTP(x;R,P)) \leq 2$

Calculate the number of spatial transitions(bitwise 0/1 changes)

	2	

Upper Pattern

Lower Pattern

0	1	1
0		1
0	0	0

Lower Pattern

$U_L(LTP(x;R,P)) \leq 2$

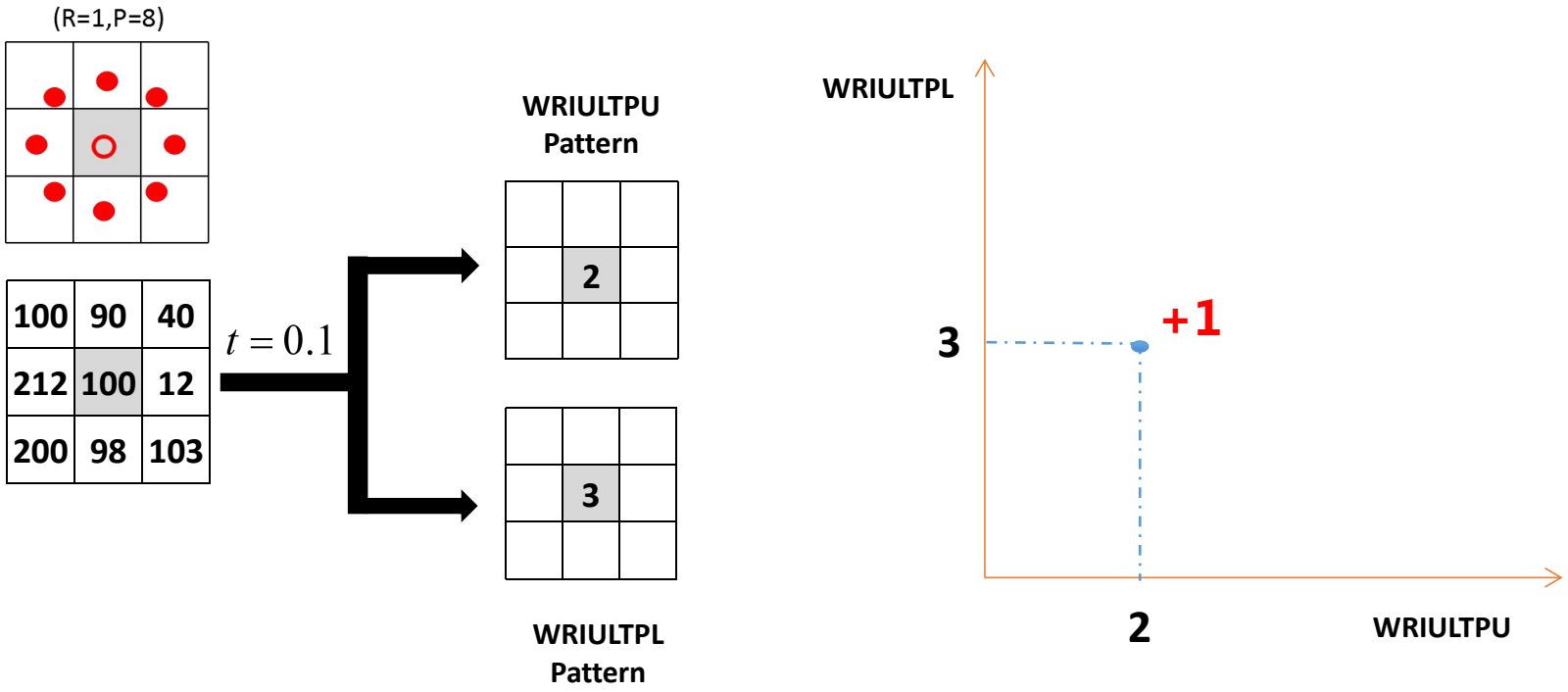
Calculate the number of spatial transitions(bitwise 0/1 changes)

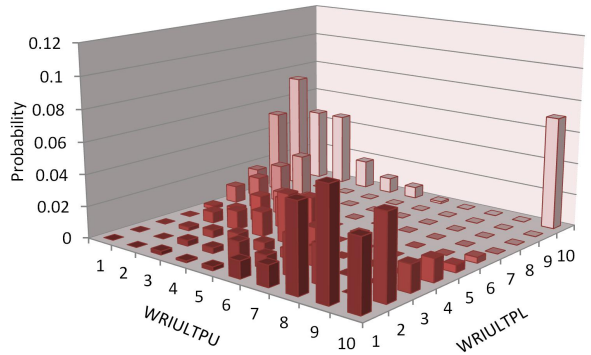
	3	

$$T_L\left(\frac{I(x_p)-I(x)}{I(x)}\right)=\begin{cases}1 & \text{if } \frac{I(x_p)-I(x)}{I(x)} \leq -t \\ 0 & \text{if } \frac{I(x_p)-I(x)}{I(x)} > -t\end{cases}$$

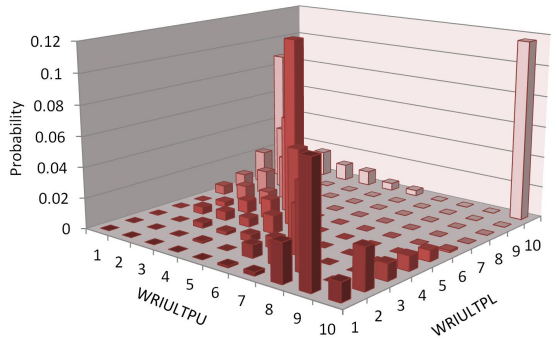
$$WLTPL^{riu2}(x;R,P)=\begin{cases}\sum_{p=0}^{P-1} T_L\left(\frac{I(x_p)-I(x)}{I(x)}\right) & \text{if } U_L(LTP(x;R,P)) \leq 2 \\ P+1 & \text{otherwise}\end{cases}$$

Methods Joint WRIULTP (JWRIULTP)





(a)CLE



(b)PSE

Fig. Examples of the joint histogram.
(a) is computed from the CLE ROI.
(b) is calculated from the PSE ROI.

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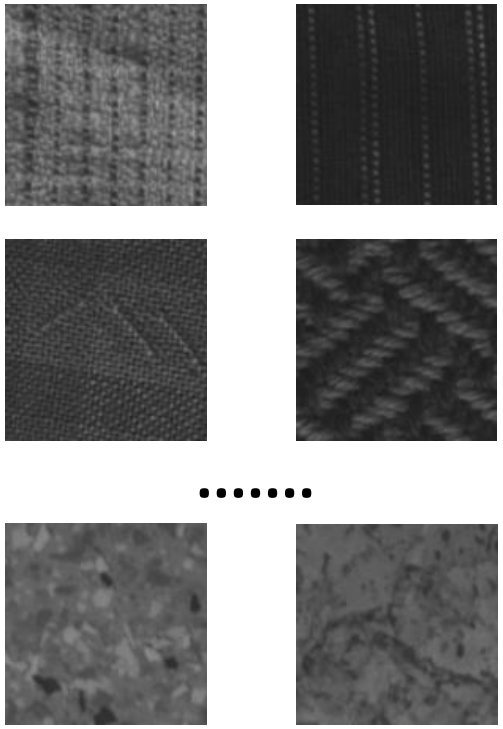
Experimental Results On the Outex database

Outex database (Texture database , public on http://www.outex.oulu.fi/)



4320 images (128×128 pixels) of **24 textures**

Training Set: 480 images

Testing Set: 3840 images

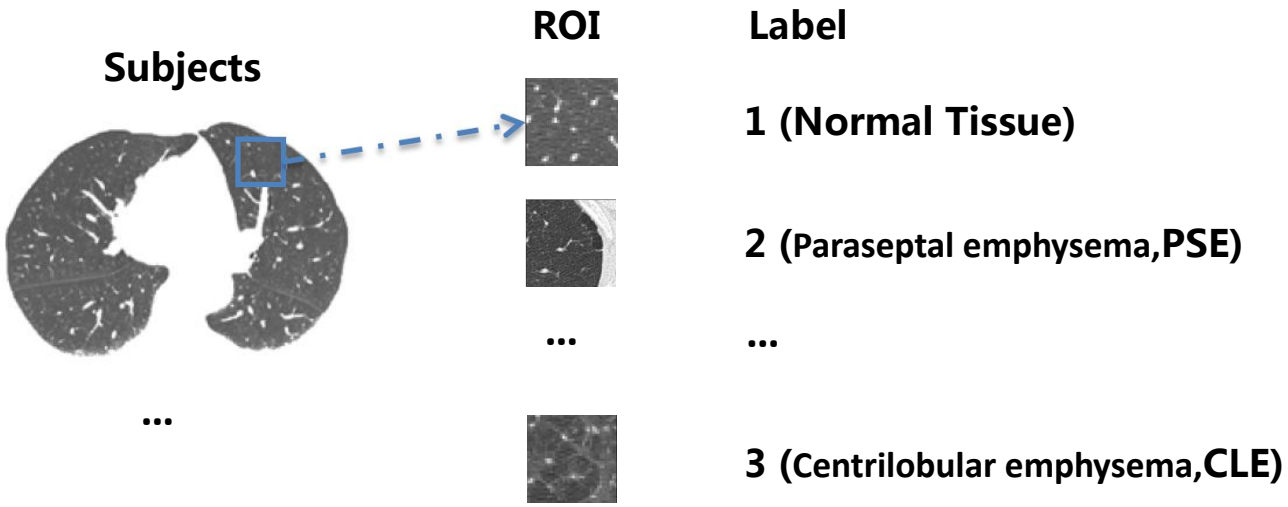
Methods	Dimension	Classification Accuracy
LBP	256	54.24%
RILBP	36	83.18%
RIULBP	10	84.35%
LTP	512(2×256)	65.70%
RIULTP	20(2×10)	**91.93%**
WRIULTP	20(2×10)	**93.05%**
JWRIULTP	100(10×10)	**95.60%**

Table 1.
The comparative results of our proposed approaches and a series of LBP-based descriptors on the Outex database.

Experimental Results On the Bruijne and Sørensen database

Bruijne and Sørensen database (Emphysema database , public on http://image.diku.dk/emphysema_database/)

168 non-overlapping ROI（61×61 pixels）(annotated manually in **25 subjects**)



Type	Number
Normal Tissue	59
CLE	50
PSE	59

Experimental Results On the Bruijne and Sørensen database

Leave one subject out

Methods	Dimension	Classification Accuracy
LBP	256	67.11%
LTP	512(2×256)	69.51%
RIULTP	20(2×10)	71.43%
WRIULTP	20(2×10)	76.19%
JWRIULTP	100(10×10)	**82.14%**
RILBP[1]	36	71.43%

Table 3.
The comparison between the best results acquired from our method and the results of other approaches on the Bruijne and Sørensen database

[1] Sorensen, Lauge, Saher B. Shaker, and Marleen De Bruijne. "Quantitative analysis of pulmonary emphysema using local binary patterns." *IEEE transactions on medical imaging* 29.2 (2010): 559-569.
[2] Gangeh, Mehrdad J., et al. "A texton-based approach for the classification of lung parenchyma in CT images." *International Conference on Medical Image Computing and Computer-Assisted Intervention*. Springer Berlin Heidelberg, 2010.

Methods	Dimension	Classification Accuracy
INT	9	86.90%
JINT1	180(2×9×10)	**95.24%**
JINT2	900(9×10×10)	**95.83%**
Texton-based[2]	30 or 120	90.48%
LBPINT[1]	324(9×36)	92.20%

Table 4.
The comparison between the results acquired from our methods and the results of other advanced techniques on the Bruijne and Sørensen database.

1)**INT**: Intensity histogram
2)**JINT1**: Firstly, we make the joint histograms of intensity and two patterns of WRIULTP respectively, and then connect them directly.
3)**JINT2**: Joint 3-D WRIULTPU, WRIULTPL and intensity histograms.
4)**Texton-based**: A texton-based approach for the classificat-ion of emphysema published in [2].
5)**LBPINT**:Joint LBP and intensity histogram for classifying emphysema published in [1].

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Conclusion

- **Extended RIULBP and LTP**, which are extensively used in a variety of computer vision applications, **into RIULTP**
- **Proposed the WRIULTP** on the basis of **Weber's law**, which is a principle of human perception.
- **Put forward** the joint Weber-based rotation invariant uniform local ternary pattern (**JWRIULTP**) by integrating the upper pattern and the lower pattern
- Our proposed strategy not only **increased classification accuracy** on the standard **texture image database**, but also improved performance on the representative **emphysema database** compared to other state-of-the-art texture descriptors.

Q&A

Thank you

ICIP 2017
IEEE International Conference on Image Processing
September 17-20, 2017, Beijing, China