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Automatic Detection of Metastatic Lung Tumors On Helical Chest CT Using Fast 3D Template Matching

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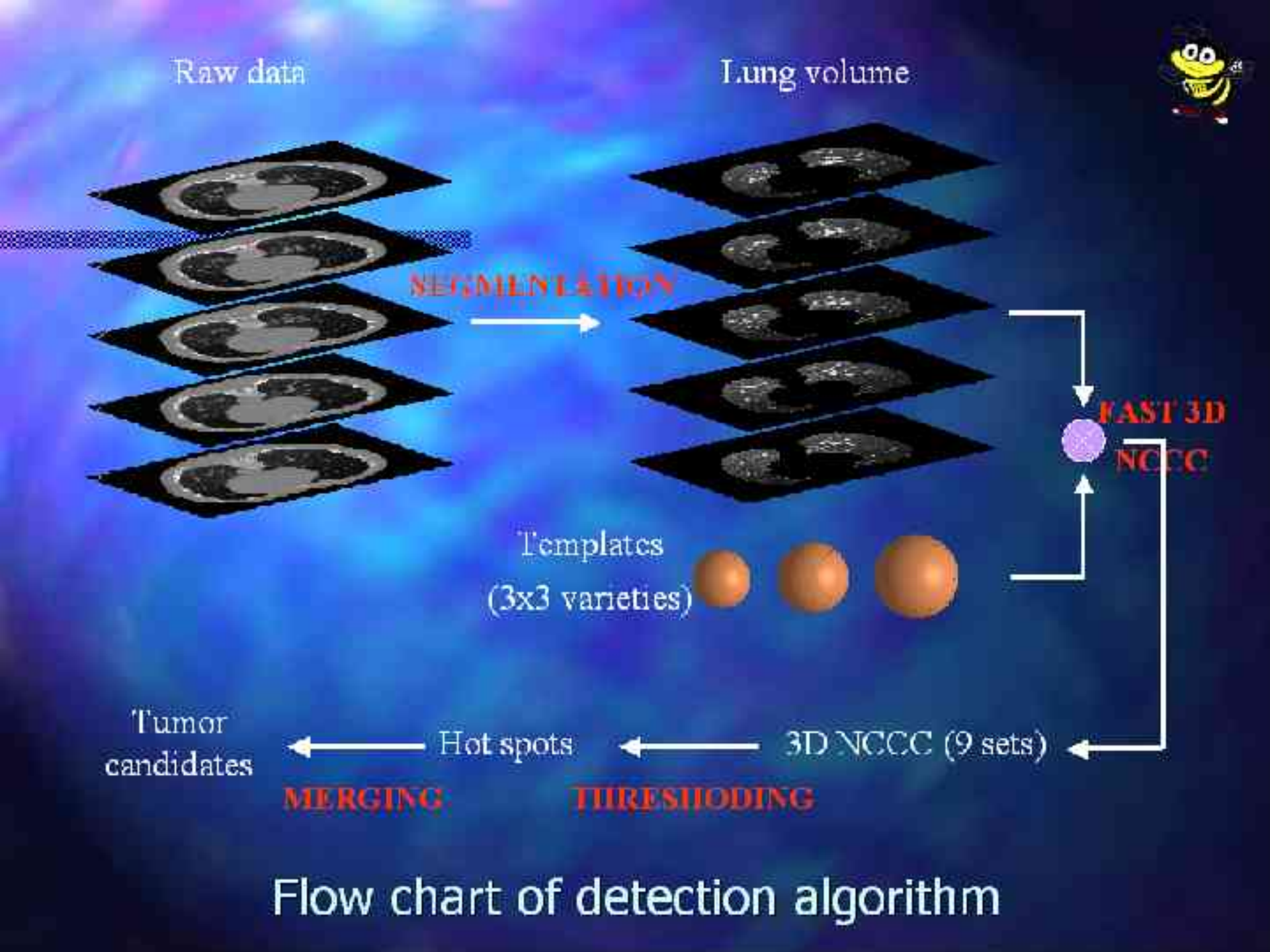
Motivation

- Helical CT scans are widely used for screening of patients with high-risk lung metastasis
- Most metastatic lung tumors tend to have approximately spherical geometry:
  - 3D spherical templates can be used to match tumors – Simulating the way radiologists interpret CT images

Aim: Find metastatic lung tumors of 5-12 mm in diameter from CT scans with ~1×1×3 mm resolution

Methods

- Fast algorithm for 3D NCCC calculation
- Creation of 3D templates
- Determination of optimal thresholds
- Segmentation of lung volume
- Merging duplicate positives



Flow chart of detection algorithm

Methods: Fast algorithm for 3D NCCC

- Definition of 3D normalized cross-correlation coefficient (NCCC)

$$NCCC(u,v,w) = \frac{\sum_{x,y,z}[f(x,y,z) - \bar{f}_{u,v,w}]\cdot[t(x-u,y-v,z-w) - \bar{t}]}{\sqrt{\sum_{x,y,z}[f(x,y,z) - \bar{f}_{u,v,w}]^2 \cdot \sum_{x,y,z}[t(x-u,y-v,z-w) - \bar{t}]^2}}$$

- Fast frequency domain algorithm to calculate the sum of cross product
- Pre-computed running sum to calculate the average and variance
- Performance:
  - For a 240×350×45 lung volume, it takes total 270s for all 9 templates (Direct calculation cost ~4 hours)

Methods: Creation of 3D templates

- Selection of templates offsets and radii

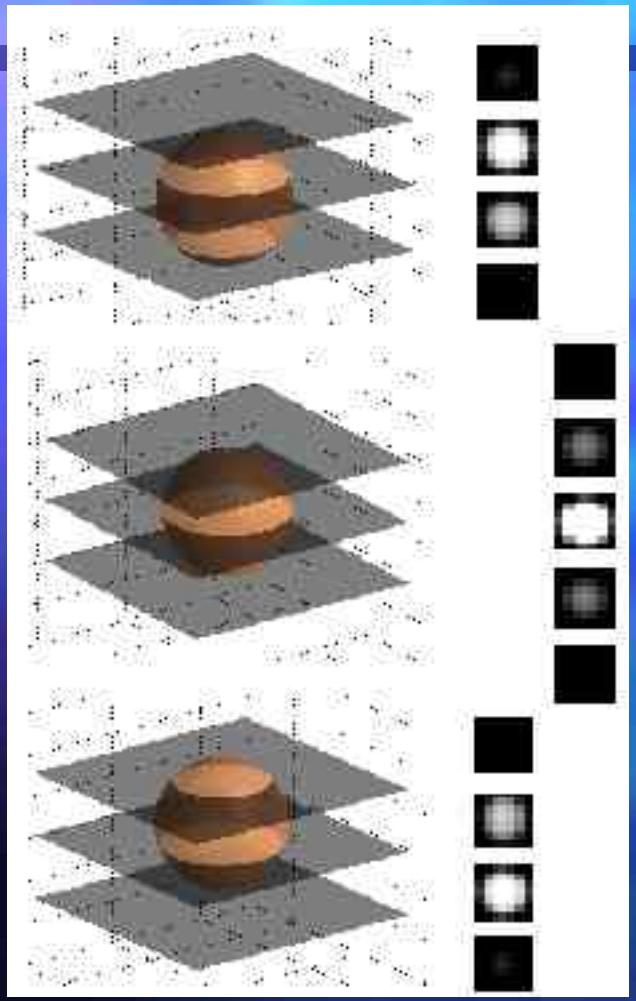
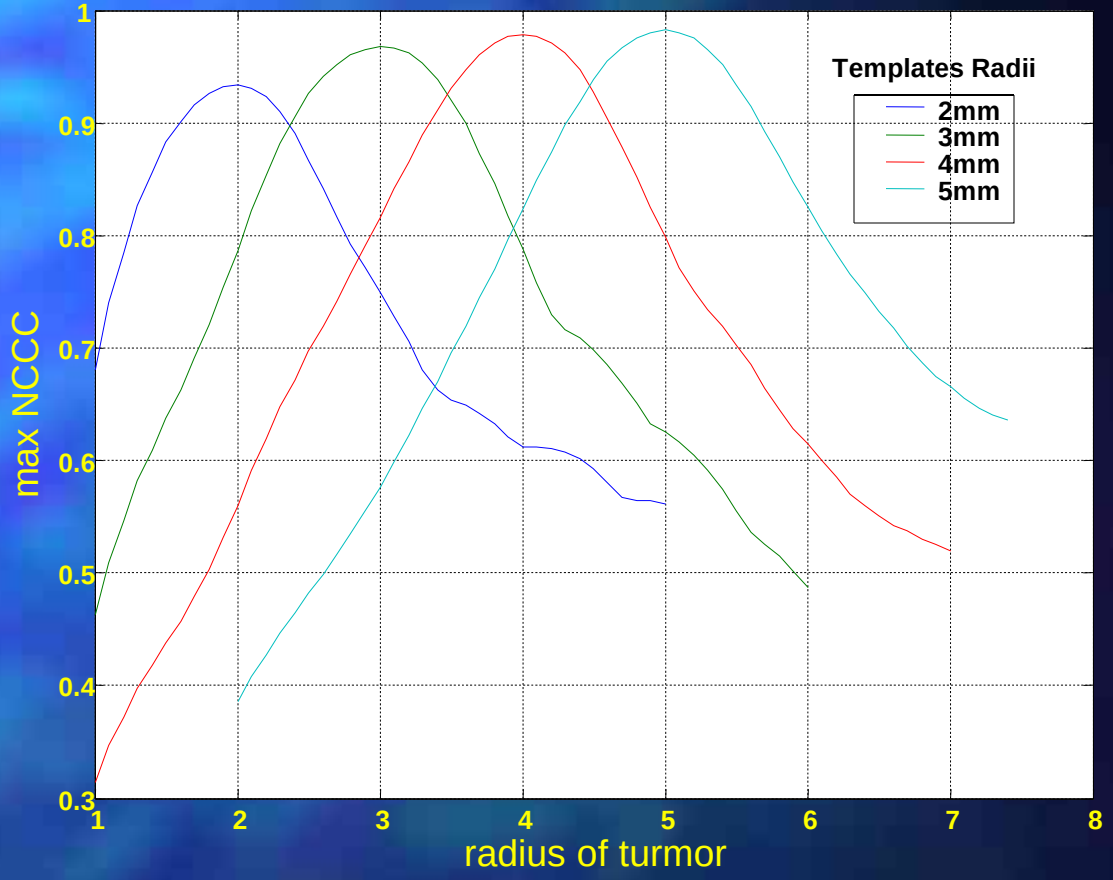


Illustration of 3 varieties of 3 mm templates



at shift of half slice thickness (1.5 mm)

maximum of the 3 NCCC vs. tumor radius

Methods: Determination of optimal thresholds

- Simulation: Insert simulated tumors into patient CT scans
  - Different shapes
    - Spheres of radii 2.25 to 6.75 mm
    - Ellipsoids with eccentricity from 1.25 to 2.0, half minor axis ranging from 2.25 to 5.25 mm
  - Edge blurred using Gaussian filter
  - Different added noise levels
- Findings:
  - Confirmed our 9 template varieties in 3 sizes are capable of picking up tumors within desired range
  - Different optimal margins and thresholds were determined for different sizes

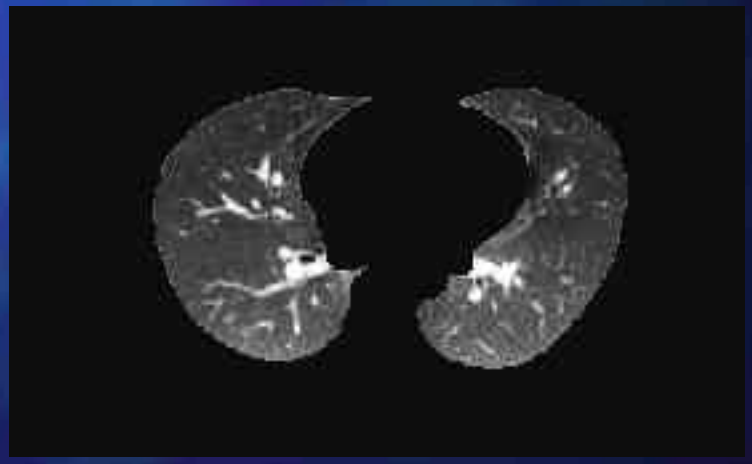
Methods: Segmentation of lung volume

Original slice

Thresholded slice

Lung contour

Cropped lung field



Methods: Merging of duplicate positives

- Tumors and false positive structures may be picked by more than one of the 9 templates
  - need to merge duplicate positives
- List 3D Coordinates of centroids of all positives, ranking them according to axial coordinate
- Merge positives within 2 mm distance

Experiments

- Datasets
- CT scans parameters
- Preliminary Results

Experiments: Datasets

- Dataset 1: patient #1
- Dataset 2: the same patient #1, scanned 24 months after radiotherapy; with different lesions
- Dataset 3: patient #2

Dataset	Thoracic slice number	Tumor number	Tumor diameter (mm)
#1	83	5	~5-14
#2	82	4	~4-10
#3	60	6	~5-10

Experiments: CT scan parameters

GE GENESIS Lightspeed CT scanner

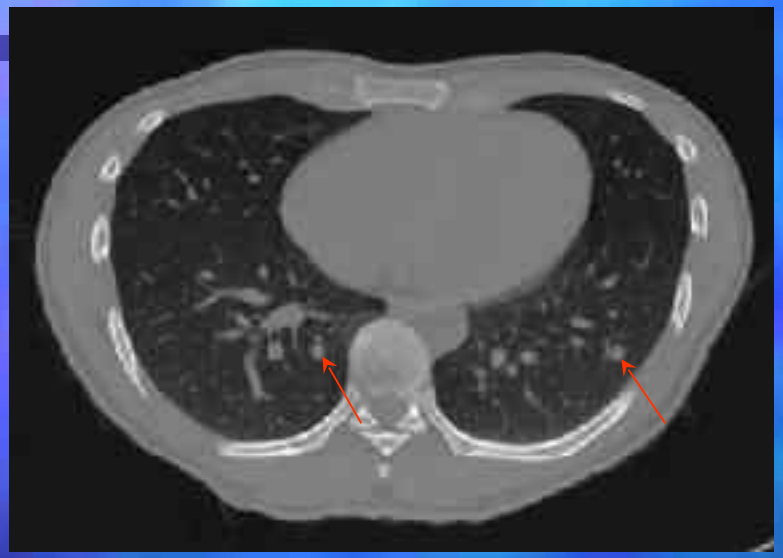
- Tube voltage: 120 kV
- Tube current: 70[#1]/140[#2,3] mA
- Exposure time: 3000[#1]/2000[#2,3] ms
- Slice thickness: 3 mm
- Slice separation: 3 mm
- In-plane resolution: 0.9375 mm
- No contrast

Experiments: Preliminary Results

dataset	thoracic slice number	number of tumors	tumor detected	total number of false positives
#1	83	5	5	5
#2	82	4	4	4
#3	60	6	6	1
Total	225	15	15	10

Examples

→ Tumors found



Conclusions

- Based on a simple model, this fast and straightforward algorithm obtained promising results in detection of lung metastatic tumors ranging 5-12 mm in diameter
- The shape of detected tumors can be approximately spherical or ellipsoidal and even more irregular
- Advantages:
  - automatic
  - low number of false positives w/o post-processing
  - is not affected by low contrast
- Disadvantages
  - may not work for spicular tumors or semi-spherical tumors attached to lung wall

Future Work

- Test on more clinical datasets
- Use smaller templates to detect smaller tumors
- Refine segmentation method
- Try larger slice thickness (5-10 mm)
- Incorporate post-processing

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