
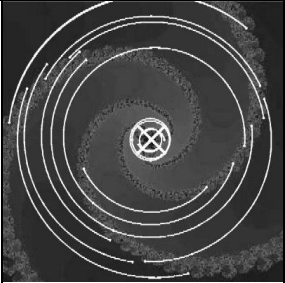
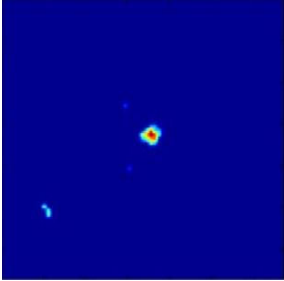
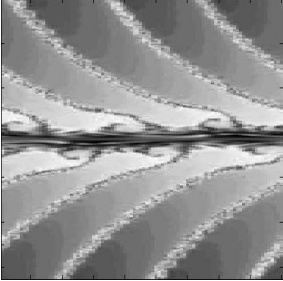
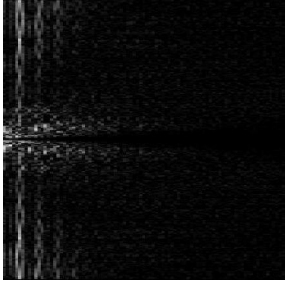
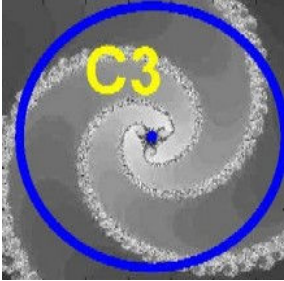
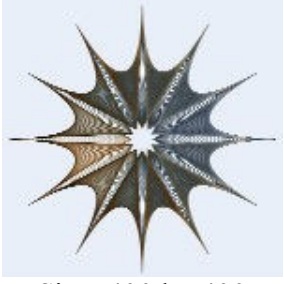
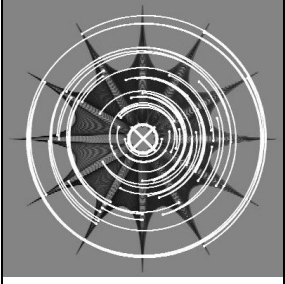
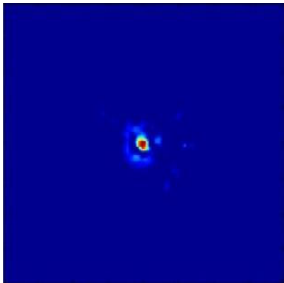
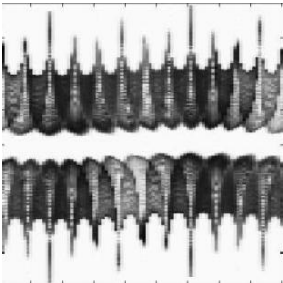
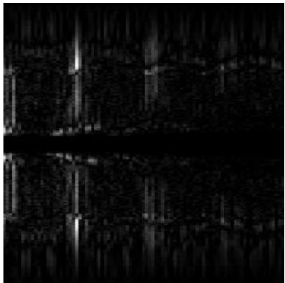
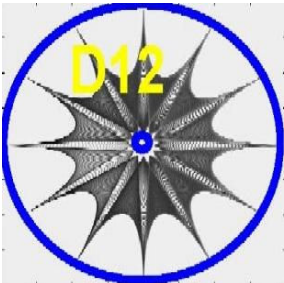


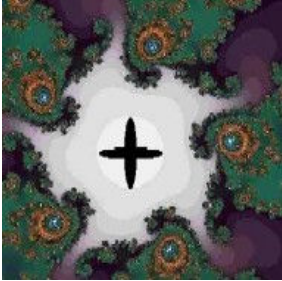

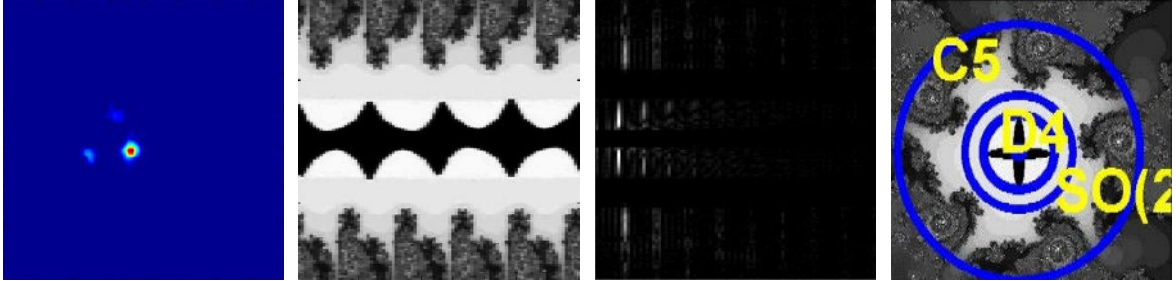
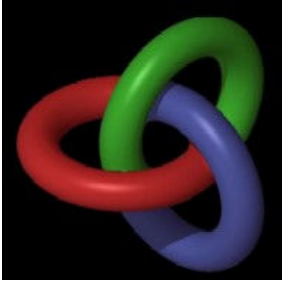
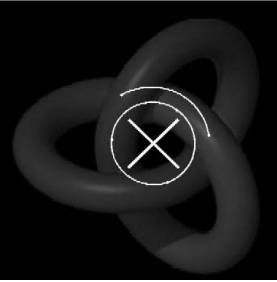
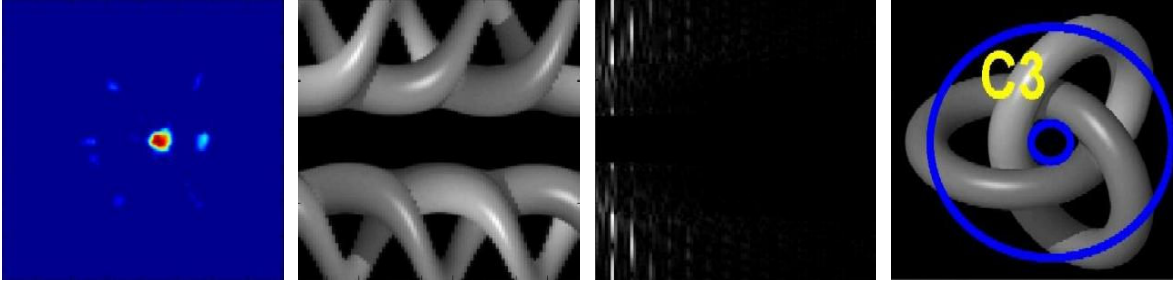
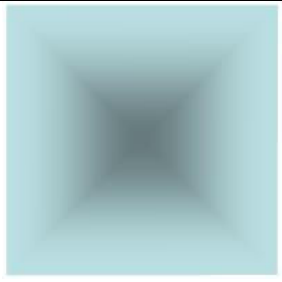
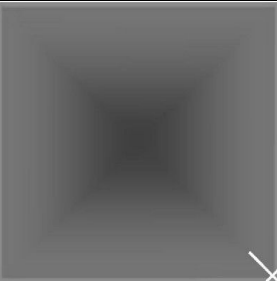
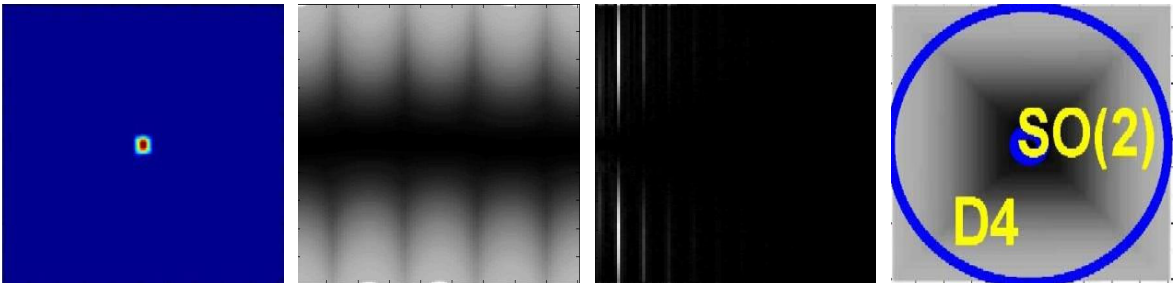
## Experimental test results and comparison our proposed rotation detection algorithm to Loy & Eklundh 2006 [1]

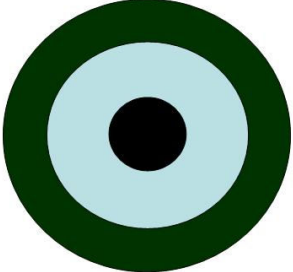
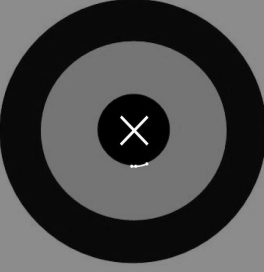
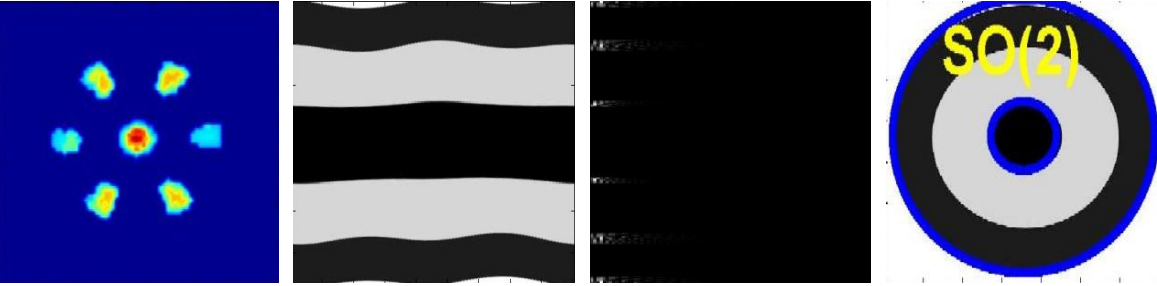
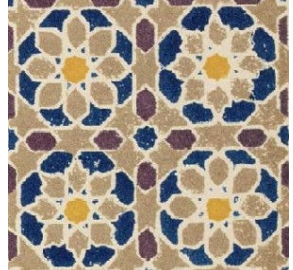
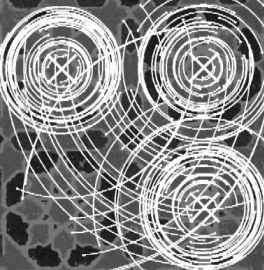
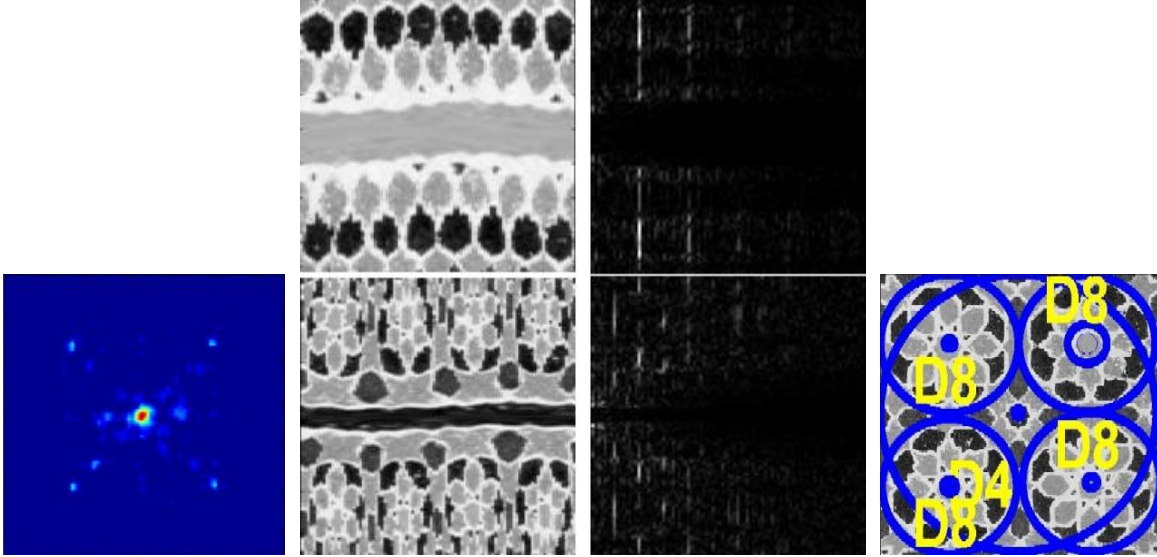
\* **Correct Detection Rates: (1) center detection; (2) # of fold (the order of the cyclic subgroup)**



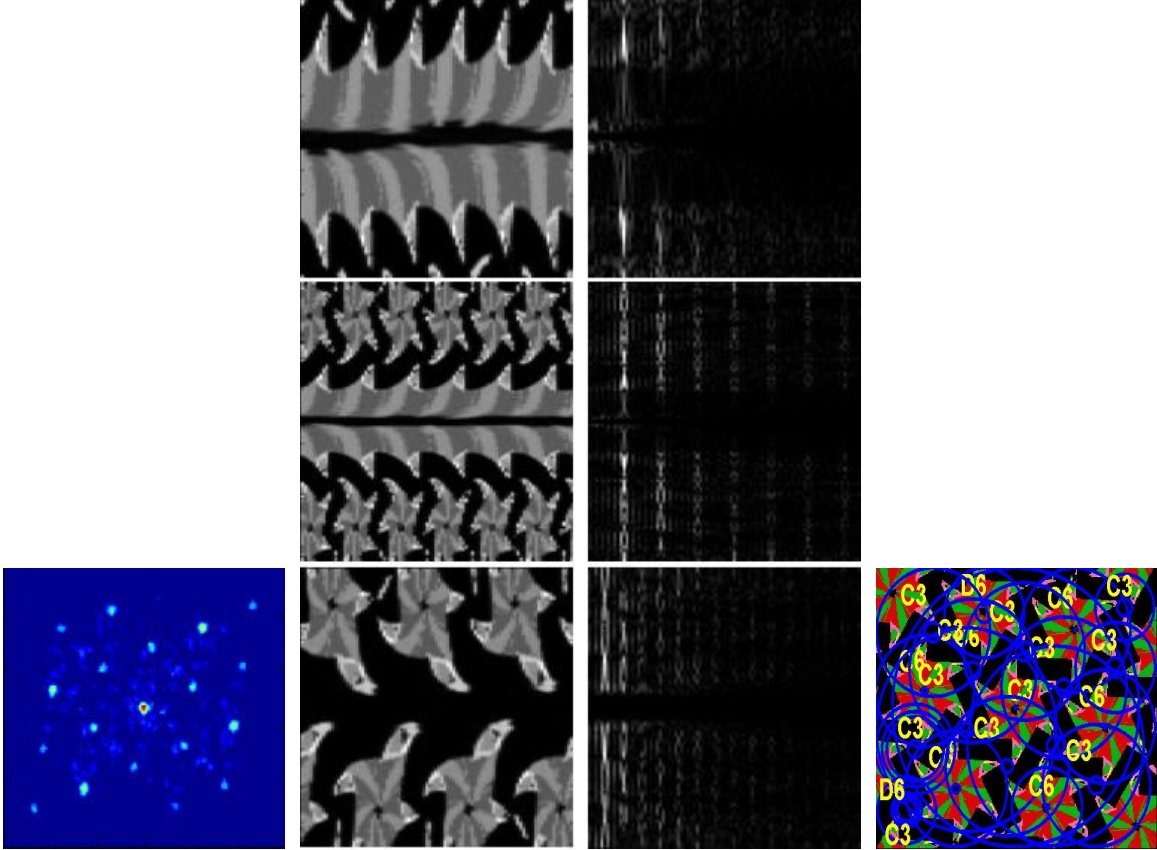

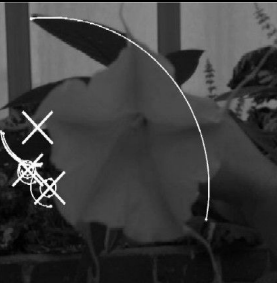
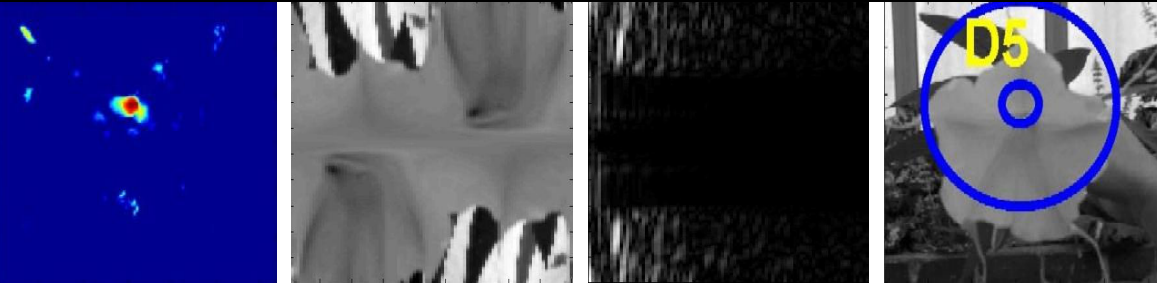
	Center	# of fold	Symmetry group	region
<b>Loy &amp; Eklundh 2006 [1]</b>	31% (14/45)	57% (8/14)	N/A	N/A
<b>Our result</b>	93% (42/45)	93% (43/46)	93% (43/46)	98% (45/46)



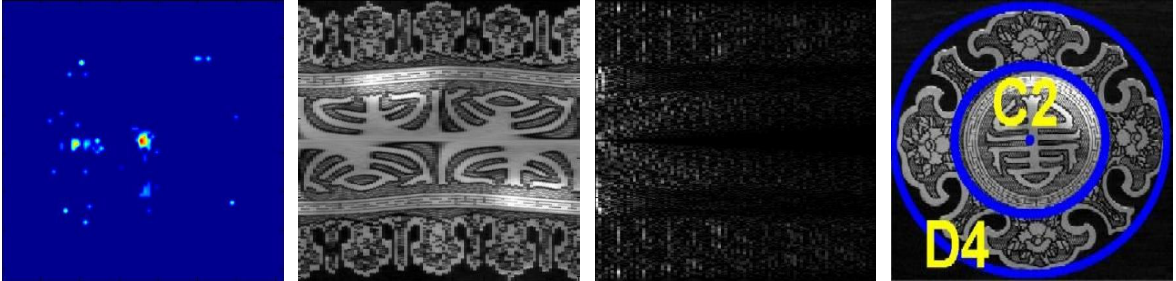

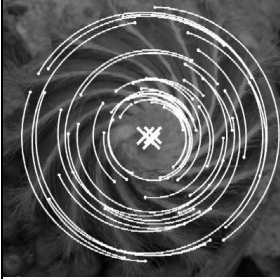
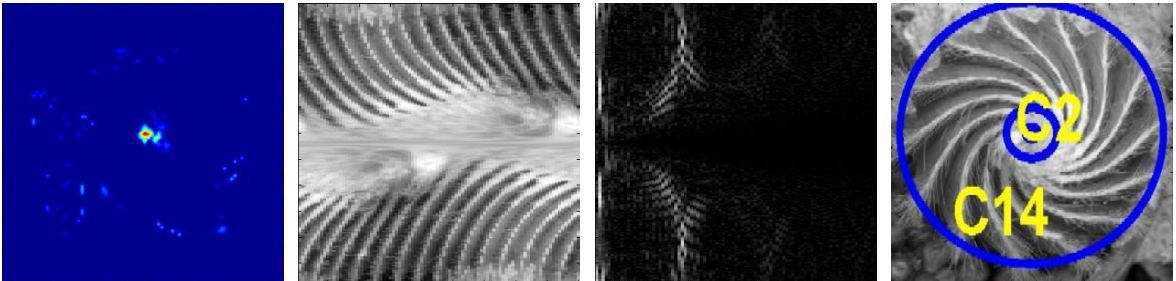


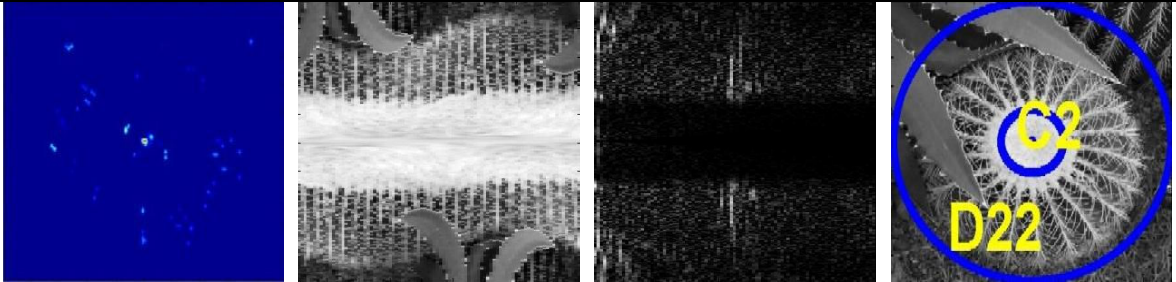
- Ground truth of centers includes all multiple rotation symmetry centers ( 45 centers total)
- D2 is a special case of dihedral group indicating reflection symmetry only, thus excluded
- Number of fold is counted only when the rotation centers are detected correctly


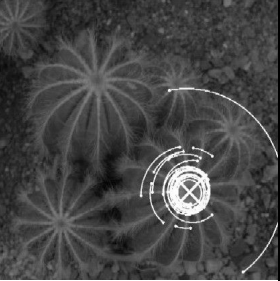
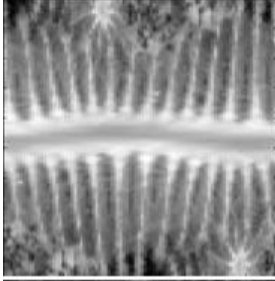
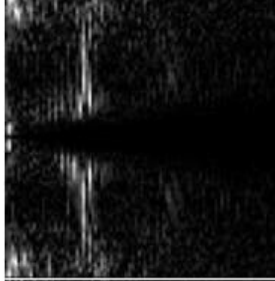
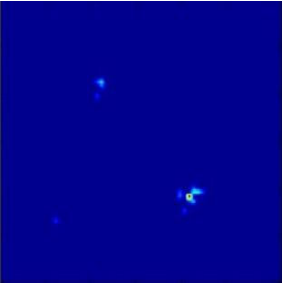
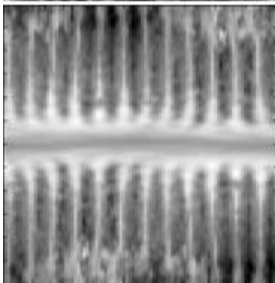
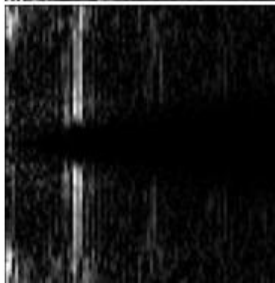
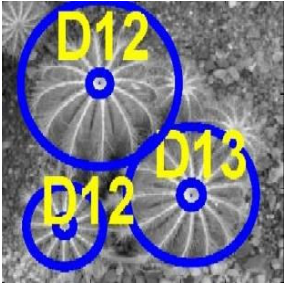
#	Original Image (Ground truth)	Loy & Eklundh 2006 [1] (Center + fold)	<b>Our result</b> (Center + fold + symmetry group + region)				
		Local feature based SIFT	Global feature based Frieze-expansion + Frequency analysis				
I-1	 <p>Size: 400 by 400 Symmetry : C3 Single center</p>	 <p>3-fold</p>	<p><b>RSS map</b></p> 	<p><b>Frieze-expansion</b></p> 	<p><b>DCT</b></p> 	<p><b>detection result</b></p> 	Pure cyclic example.
I-2	 <p>Size: 400 by 400 Symmetry : D12 Single center</p>	 <p>12-fold</p>				<p><b>D12</b></p> 	Pure dihedral example.

<p><b>I-3</b></p>	 <p>Size: 397 by 375 Symmetry : 5-fold Cyclic 4-fold Dihedral SO(2) Single center</p>	 <p>5-fold</p>	 <p>Concentric multiple symmetry groups are detected with exact their regions. Loy &amp;Eklundh[1] deal these different symmetry groups as single rotation symmetry.</p>
<p><b>I-4</b></p>	 <p>Size: 400 by 415 Symmetry : C3 Single center</p>	 <p>3-fold</p>	 <p>Robust to the color difference.</p>
<p><b>I-5</b></p>	 <p>Size: 200 by 200 Symmetry : D4 Single center</p>	 <p>Failed</p>	 <p>Loy &amp;Eklundh[1] fails to find keypoint features from the SIFT and failed.</p>

<p><b>I-6</b></p>	 <p>Size: 362 by 346 Symmetry : SO(2) Single center</p>	 <p>No-fold result</p>	 <p>Loy &amp;Eklundh[1] result is supported by only one point pair on the edge of inner circle. Loy &amp;Eklundh[1] do not detect SO(2).</p>
<p><b>I-7</b></p>	 <p>Size: 331 by 329 Symmetry : D8,D4,D2 5 centers</p>	 <p>8-fold Processing time = 31sec</p>	 <p>This result shows the stability of our algorithm detecting all existing symmetry. Loy &amp;Eklundh[1] fails to detect bottom-left 8-fold symmetry and global 4-fold symmetry.</p>

<p>I-8</p>	 <p>Size: 297 by 262 Symmetry : C6,C3 19 centers</p>	 <p>6-fold</p>	 <p>All local and global symmetries are found.</p>
<p>I-9</p>	 <p>Size: 320 by 300 Symmetry : D5 Single center</p>	 <p>Wrong center</p>	 <p>Near-regular case. This shows how local feature based algorithm fails. Investigating local features only can loose global truth and gives unreasonable centers.</p>

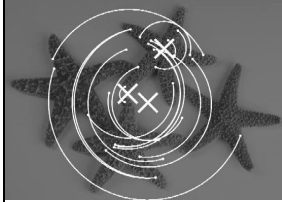
<p><b>I-10</b></p>	 <p>Size: 400 by 400 Symmetry : D4 Single center</p>	 <p>No fold result</p>	 <p>Inside region has bilateral reflection symmetry.</p>
<p><b>I-11</b></p>	 <p>Size: 580 by 580 Symmetry : C14 Single center</p>	 <p>8-fold 7-fold</p>	
<p><b>I-12</b></p>	 <p>Size: 500 by 496 Symmetry : D22 Single center</p>	 <p>5-fold 9-fold Processing time = 99sec</p>	 <p>Very high-order symmetry and exact detection result regardless of occlusion. Image is rather skewed and the region of upper part is deviated. With the high textured image, Loy &amp;Eklundh[1] takes longer time than our algorithm. Processing time = 38sec</p>

<p>I-13</p>						
	<p>Size: 314 by 300 Symmetry : D12,D13,D3 6 centers</p>	<p>7-fold</p>				
<p>This shows exact number of fold detection results (D12 and D13) with real high textured image. First and second cacti are skewed, but the result is good.</p>						

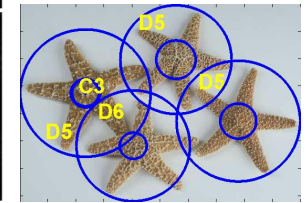
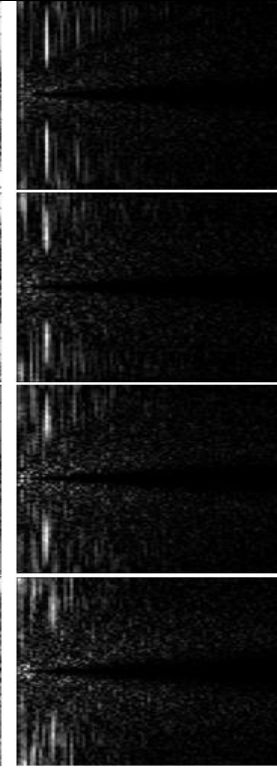
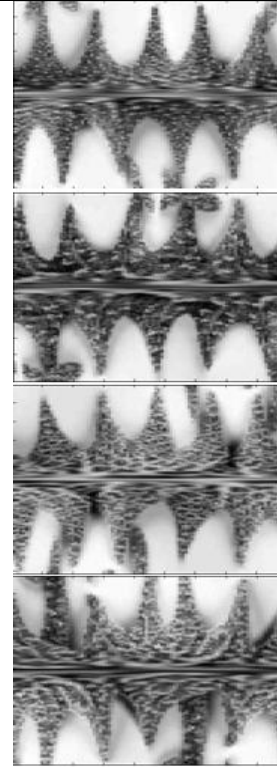
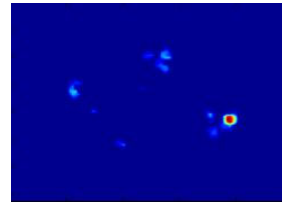
I-14



Size: 500 by 361  
Symmetry : D5  
4 centers



Wrong center

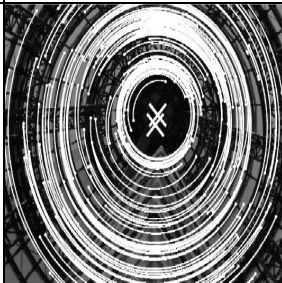


Fourth result is D6 because one leg of another starfish is connected nearby, so the starfish looks like it has 6 legs. Count the number of leg in fourth frieze-expansion. It's six.  
This reveals the weakness of local feature based method well.

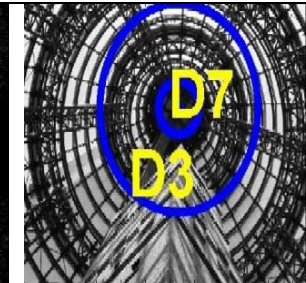
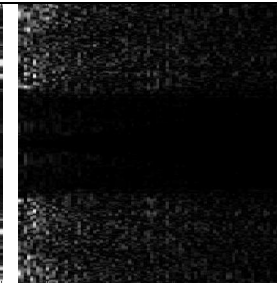
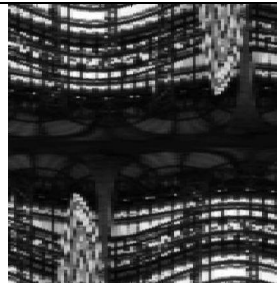
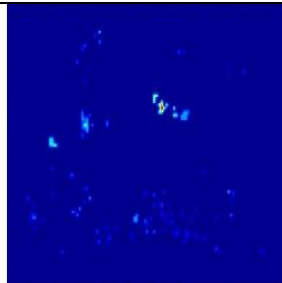
I-15



Size: 576 by 433  
Symmetry : D  
Single center


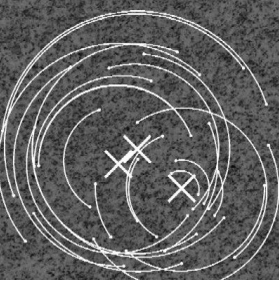
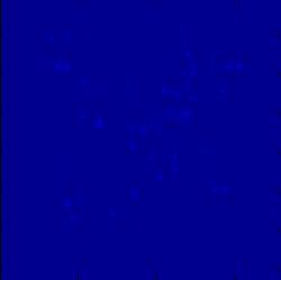


6-fold  
12-fold  
Processing time  
= 114sec



Symmetry center is detected correctly, but the symmetry group is wrong.  
Frieze-expansion shows that the image is skewed, which causes  
With the high textured image, Loy &Eklundh[1] takes longer time than our algorithm.



<p><b>I-16</b></p>	 <p>Size: 360 by 360 Symmetry : No symmetry</p>	 <p>2-fold 8-fold 9-fold Processing time = 55sec</p>	 <p>RSS map shows there is no significant peak point at all. This tells us that there is no symmetry. Our algorithm stops further process and gives 'No symmetry' result. Loy &amp;Eklundh[1] result shows how local feature based algorithm can give unreasonable result. Each local feature might have correspondence, but it does not always tell us about the whole image.</p>
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