Symmetry Detection Competition

Evaluation Details

PART I: Reflection and Rotation Symmetries

Our Team

– Ingmar Rauschert (PSU)
Summary

– Kyle Brockelhurst (PSU)
Translation symmetry

– Jingchen Liu (PSU)
Reflection symmetry

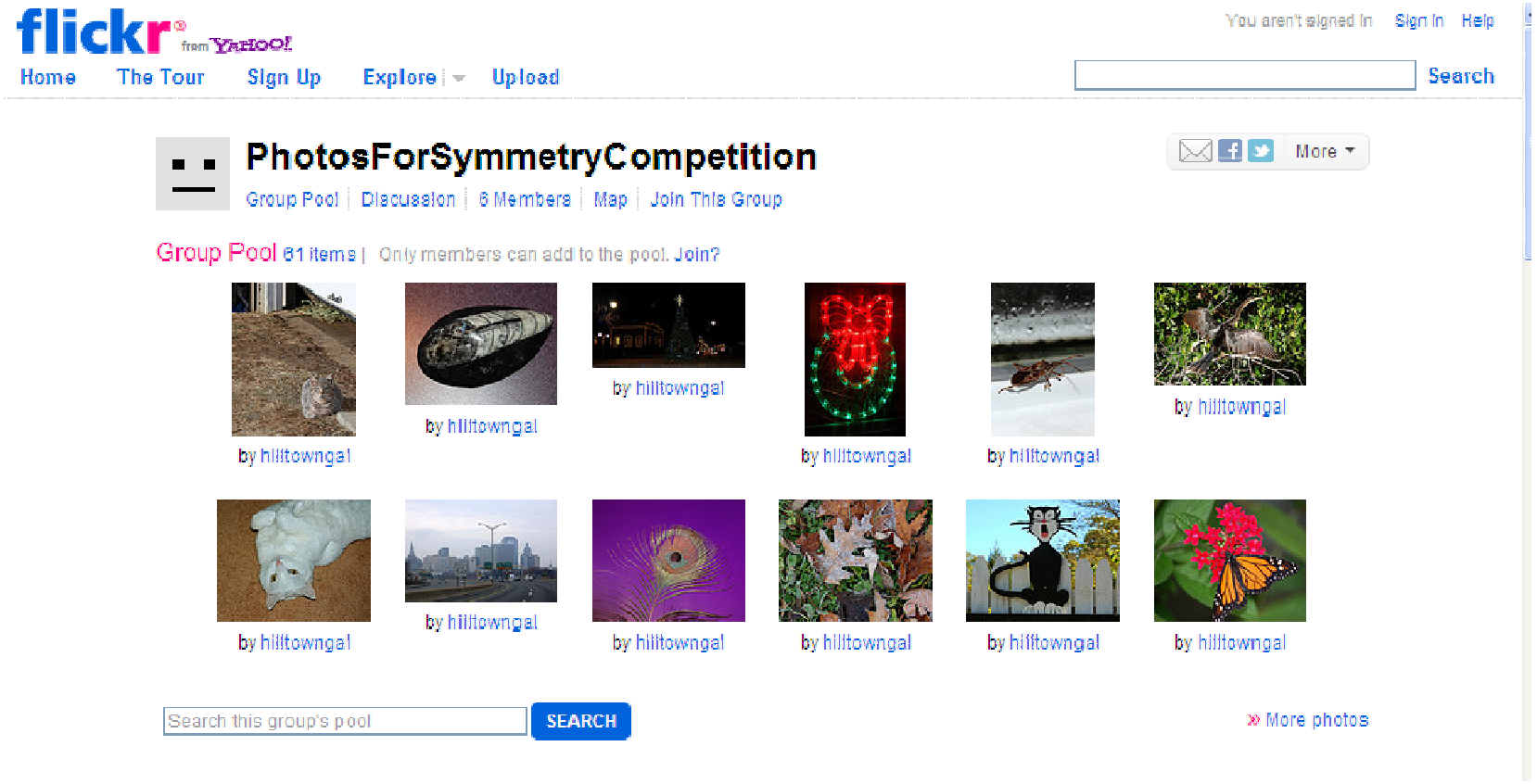
– Somesh Kashyap (BBT)
Rotation symmetry

– Yanxi Liu
Lead

Tasks

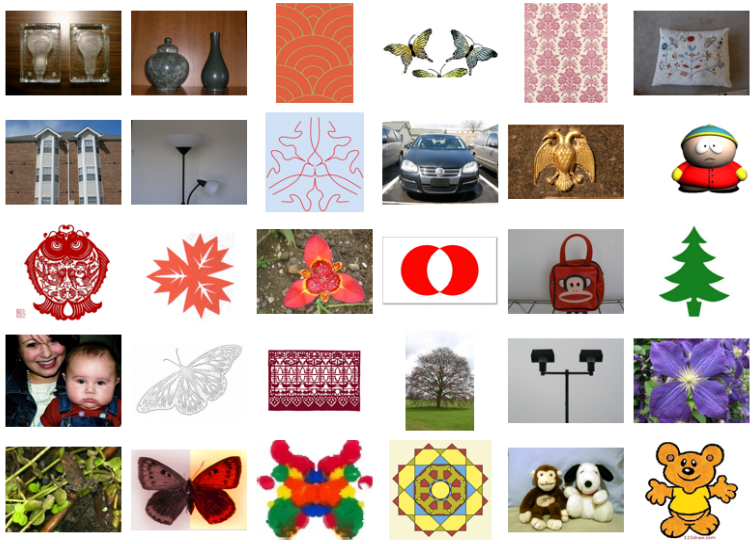
- Image Collection
- Image Annotation
- Algorithm Execution
- Algorithm Evaluation
- Presentation

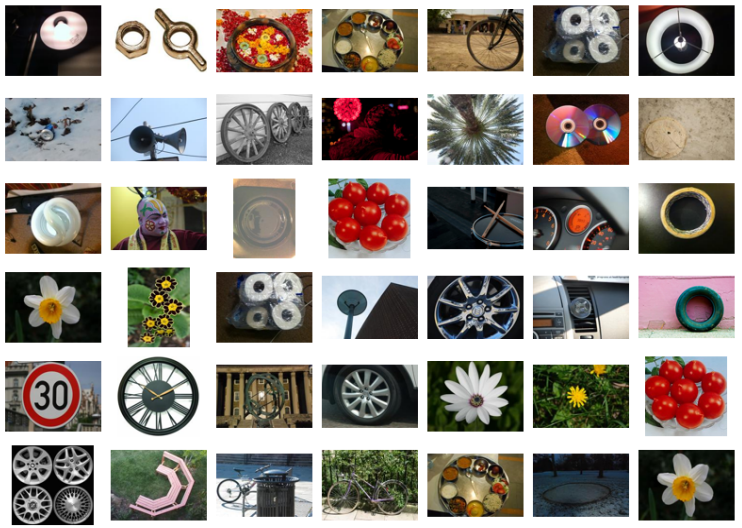
Image Collection



- WWW & Flicker
- Personal Images

Image Data Set





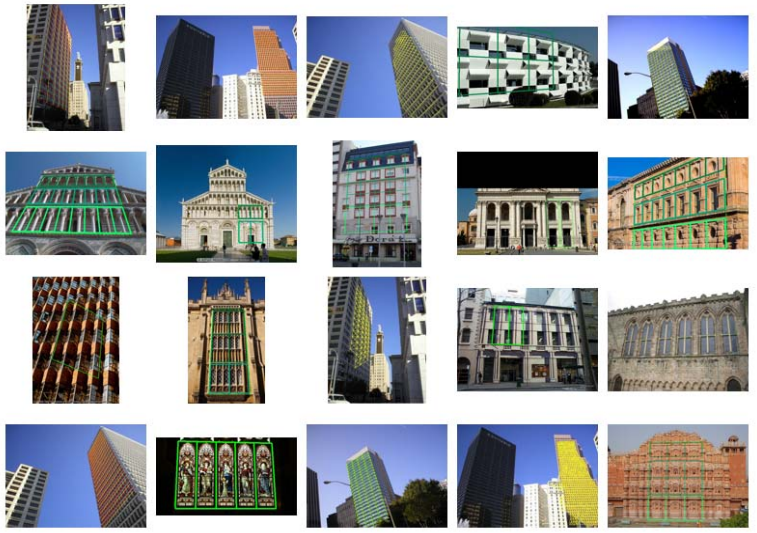
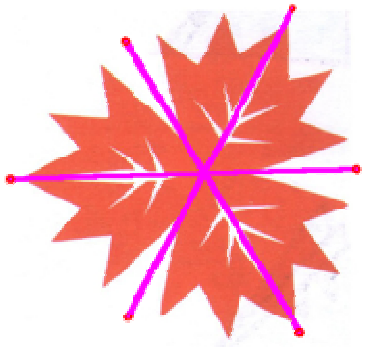
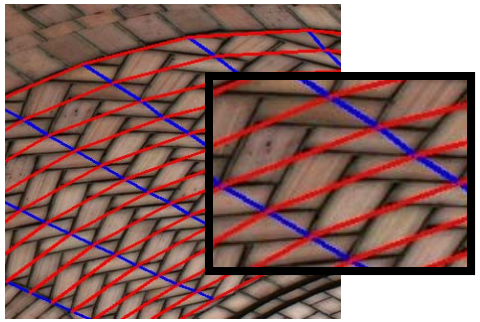


Image Annotation

- Number of training sets: 4
- Number of test sets: 6
- Number of images: 124
- Number of annotated reflection and rotation symmetries: 167
- Number of wallpaper tiles: >2000





Algorithm Evaluation

- Algorithms evaluated (Total: 11)
  - Reflection: 3 (submitted) + 1 (baseline)
  - Rotation: 3 (submitted) + 1 (baseline)
  - Translation: 2 (submitted) + 1 (baseline)
- Quantitative evaluation metrics
- Automatic processing

Algorithm Execution

- Submitted Code
  - Matlab
  - Windows Executables

- Running Code
  - Some had GUI
    - Nice, but difficult to automate for batch processing
  - Some had single point of entry
    - result = symDetect(image);
  - Some had complicated pipelines
    - imgPP1 = doPreProcessing(image, params1)
    - imgPP2 = doOtherProcessing(imgPP1, params2)
    - ….
    - Result = finallyDoSymDetect(imgPPN, paramsN)
  - Some code did not work at all
    - Only after communication with authors resolved
  - Some code still crashes on some images

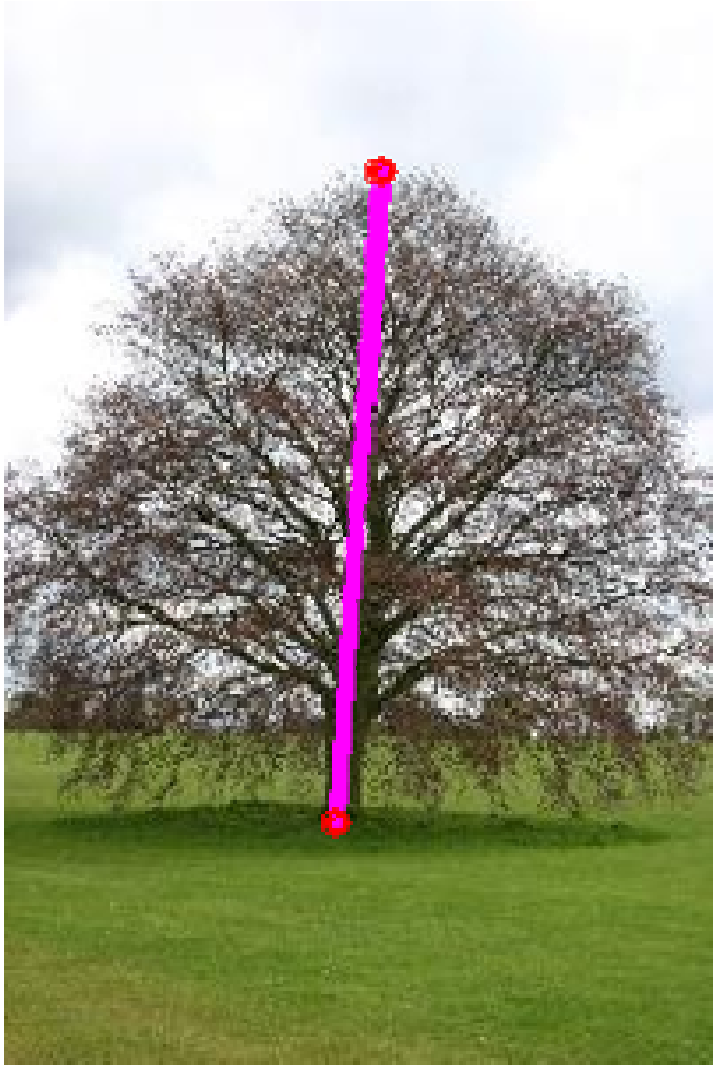
Top Contesters

- **Reflection Symmetry**
  - Mo and Draper, Colorado State, **USA**
  - Kondra and Petrosino, Uniparthenope, Napoli, **Italy**
- **Rotation Symmetry**
  - Kondra and Petrosino, Uniparthenope, Napoli, **Italy**
  - Kim, Cho and Lee, Seoul National University, **South Korea**
- **Translation Symmetry**
  - Cai, Polytechnic, Hongkong, **China**
  - Wu, University of North Carolina, **USA**

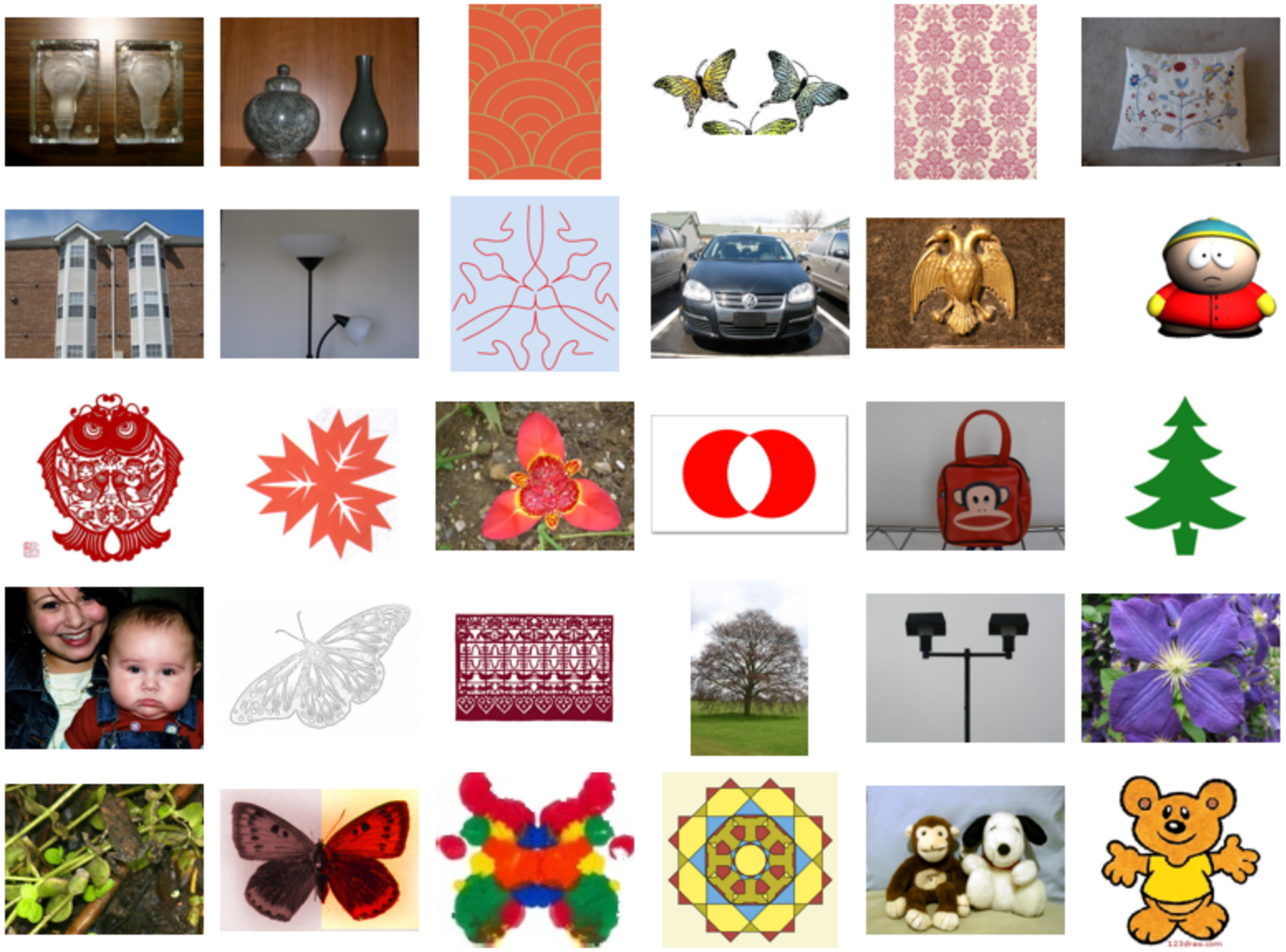
Algorithm Evaluation: Baseline Algorithms

- **Baseline Algorithms** (code/executable publicly available) :
- **Reflection Symmetry and Rotation Symmetry Detection**
  - **Loy,G. and Eklundh,J**. (2006), Detecting symmetry and symmetric constellations of features, ECCV 2006.
- **Translation Symmetry Detection**
  - **M. Park**, K. Brocklehurst, R. T. Collins, and **Yanxi Liu** (2009), Deformed Lattice Detection in Real-World Images using Mean-Shift Belief Propagation, IEEE Transaction on Pattern Analysis and Machine Intelligence (TPAMI). Vol. 31, No. 10.

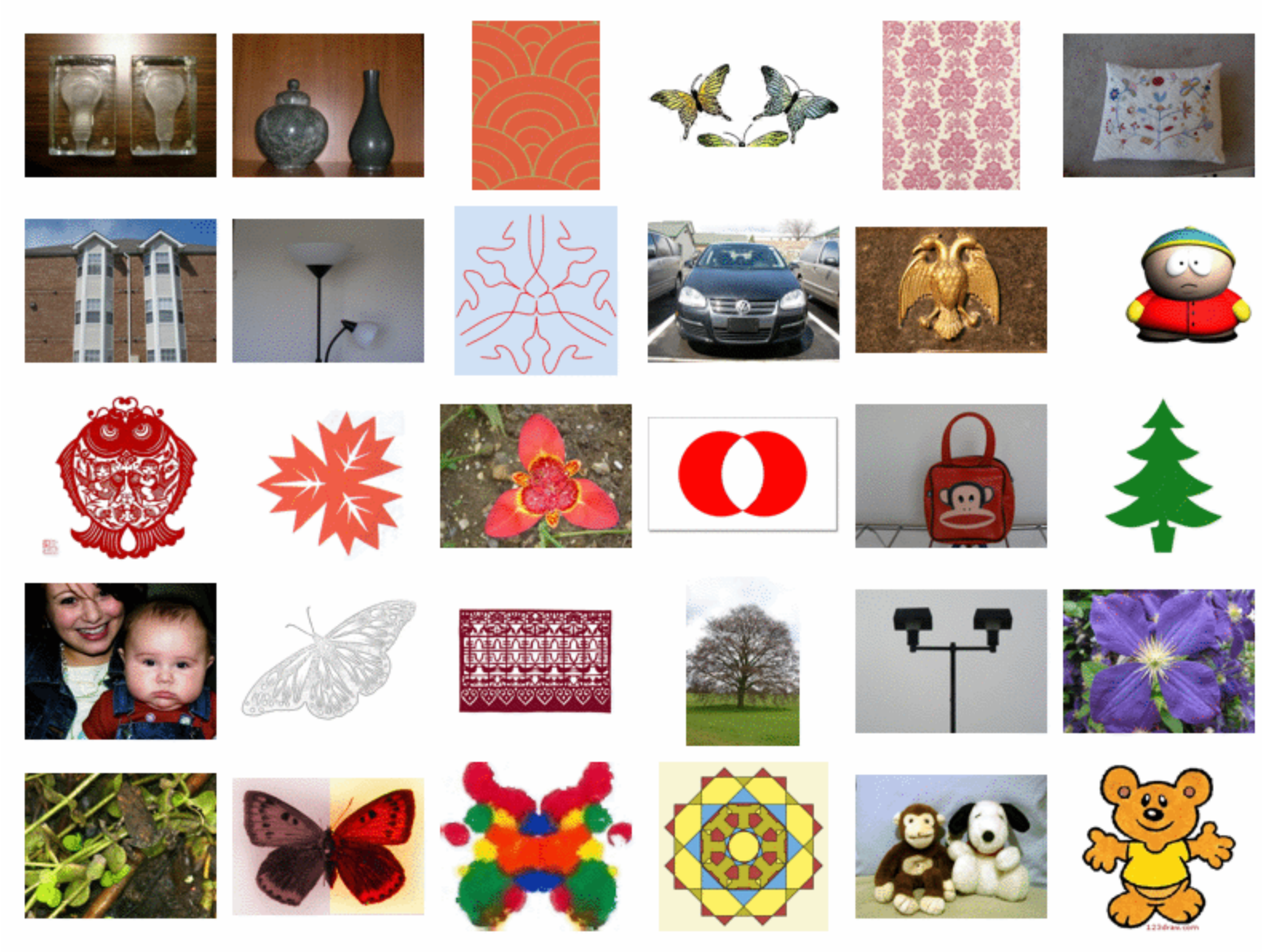
Reflection Symmetry Detection



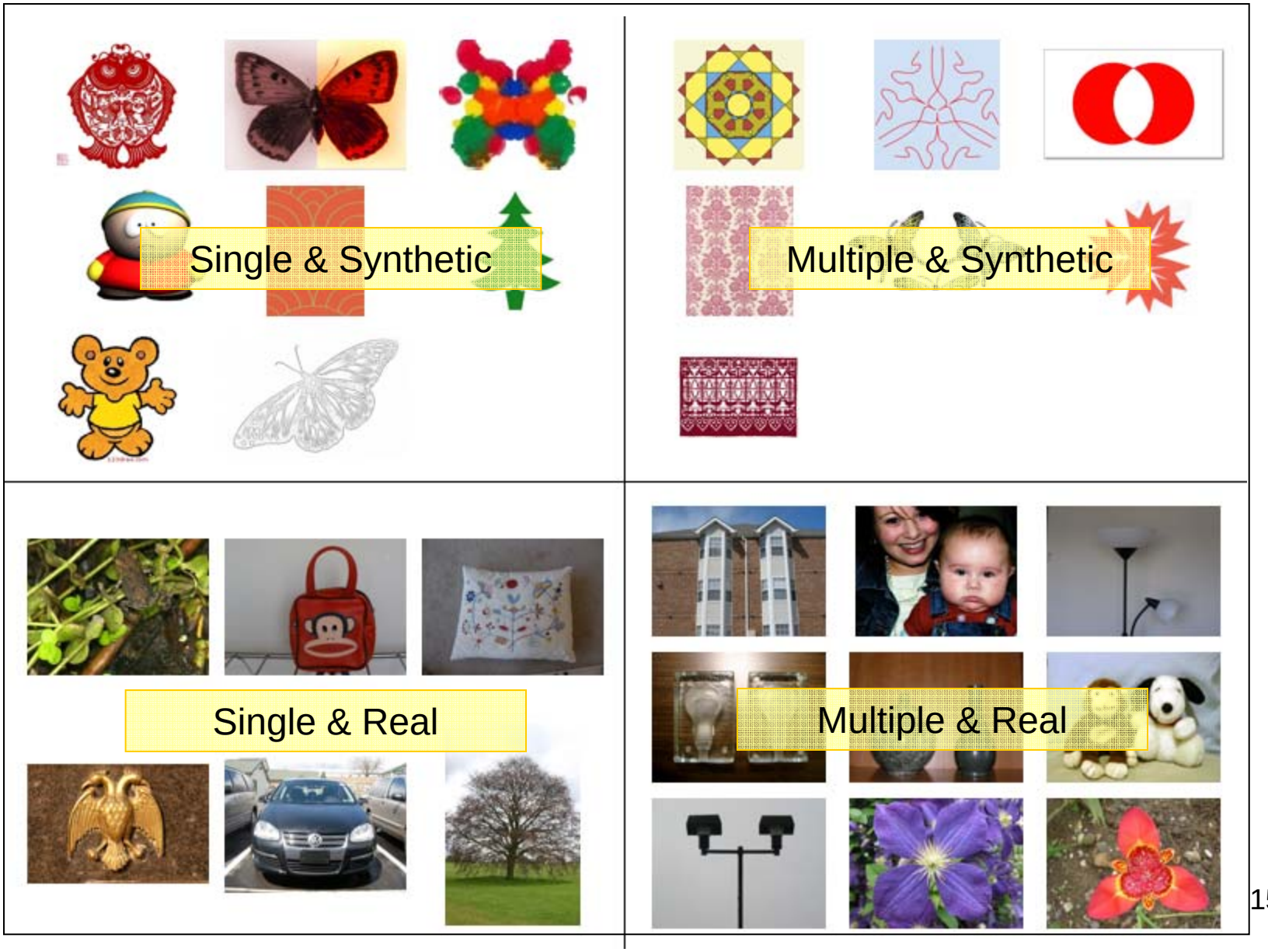
Reflection Symmetry Detection



Reflection Symmetry Detection

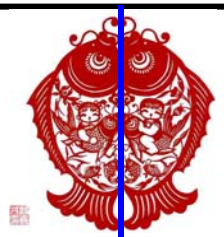
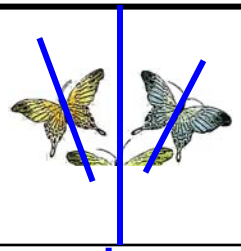
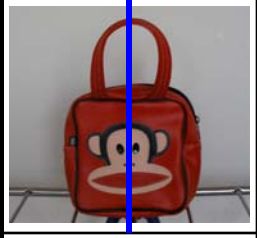
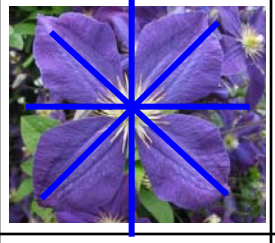


Reflection Symmetry Detection



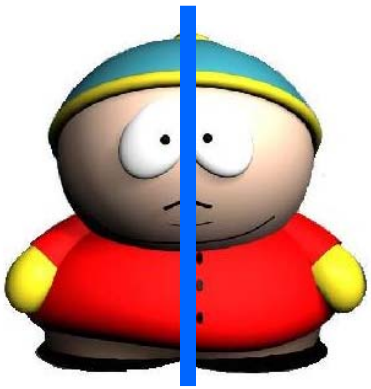
Reflection Symmetry: Test Image Categories

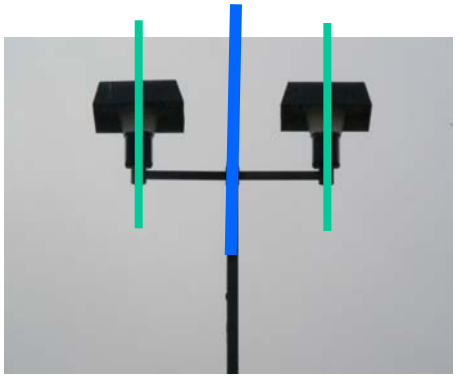
- 30 images (synthetic and real world)
- Avg. image size (600x400 pixels)
- 66 reflection axis
- 4 categories (synthetic/real x single/multiple axis)

	Single			Multiple			Total	
Synthetic		**#Imgs**	**#Syms**		**#Imgs**	**#Syms**	**#Imgs**	**#Syms**
		8	**8**		**7**	**30**	**15**	**38**
Real		**6**	**6**		**9**	**22**	**15**	**28**
Total		**14**	**14**		**16**	**52**	**30**	**66**

Reflection Symmetry: Groundtruth Labeling

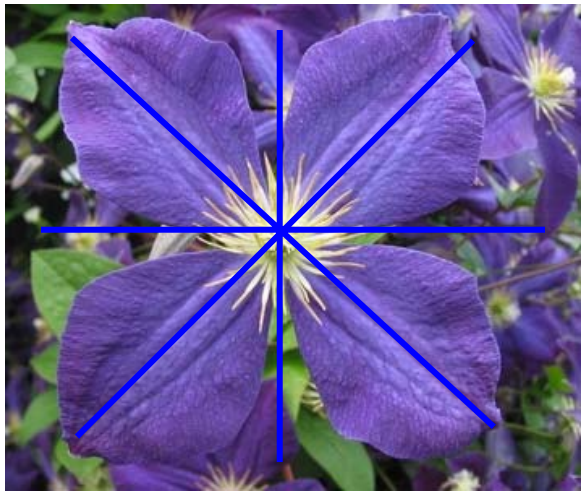
Single Symmetry Axis	Multiple Symmetry Axes	Hierarchical Symmetry Axes

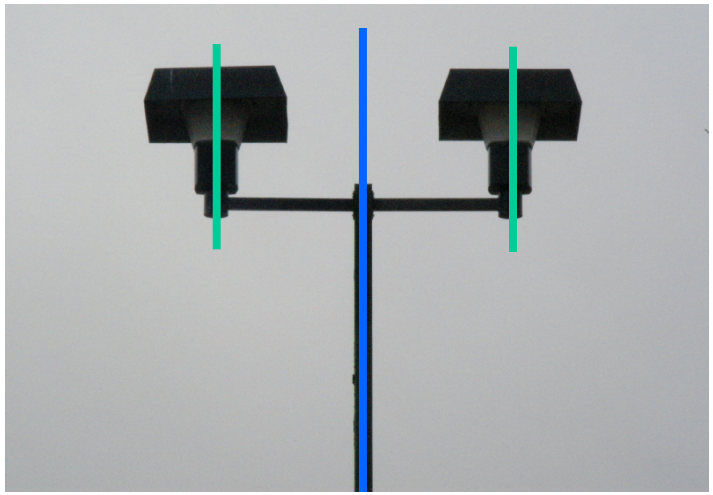




Reflection Symmetry: Groundtruth Labeling

- Total number of axis annotations: 66
- Manual annotation
  - ~10 human annotators
  - Images with dissagrement not included
- Axis defined as line with start and end point
  - [p1, p2]



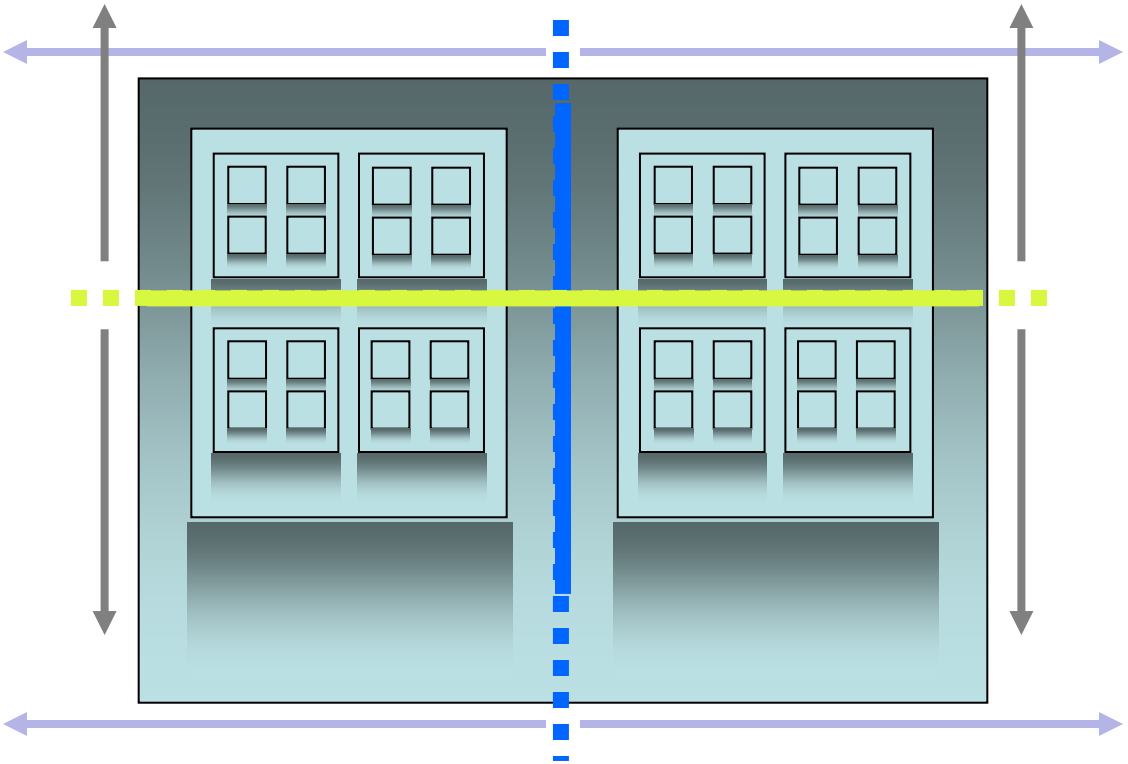


Reflection Symmetry: Groundtruth Labeling

- Groundtruth labeling can be ambiguous
  - What constitutes a valid groundtruth?
    - Application/Intend
    - Individual Annotator
  - What causes ambiguity?
    - Scale/Hierarchy
    - Tolerance for shape similarity
    - Many other factors

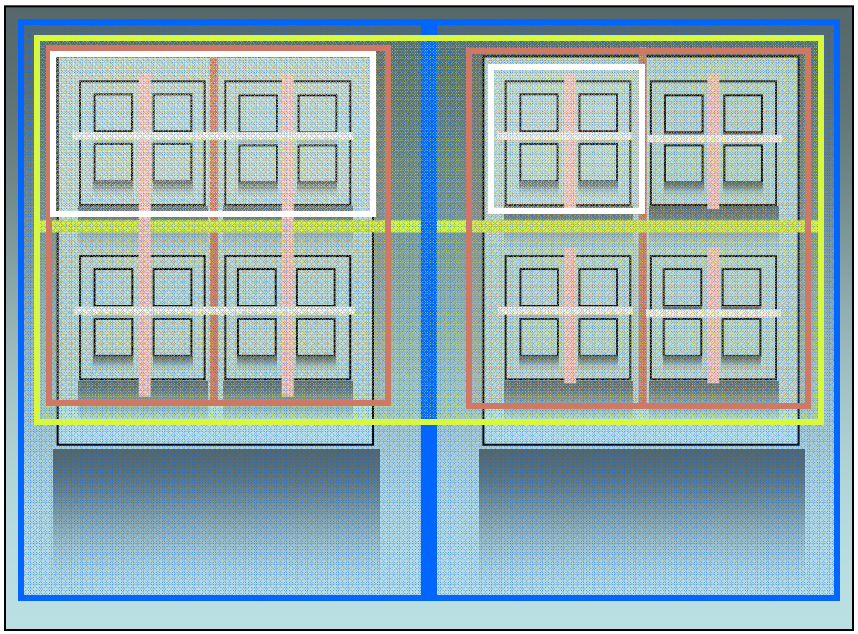
Groundtruth Labeling Ambiguity

- Hierarchical reflection symmetries
  - Local versus global reflection symmetry
    - Reflection symmetry is defined wrt a set of points S, normally S = all image pixels
    -



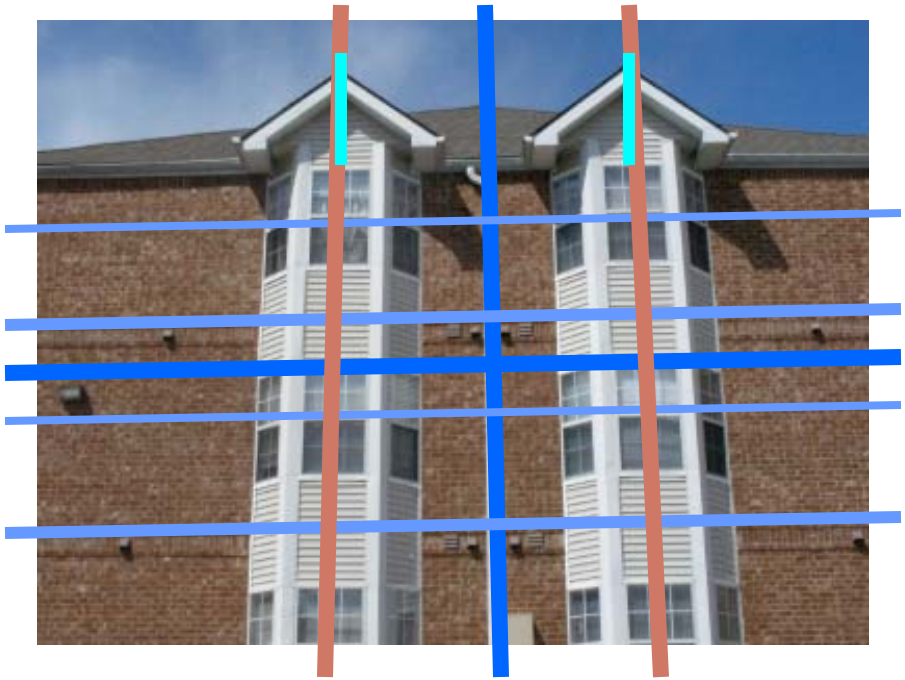
Groundtruth Labeling Ambiguity

- Hierarchical reflection symmetries
  - Local versus global reflection symmetry
    - Reflection symmetry is defined wrt a set of points S, normally S = all image pixels
    - In practice, only subsets S' of S are considered



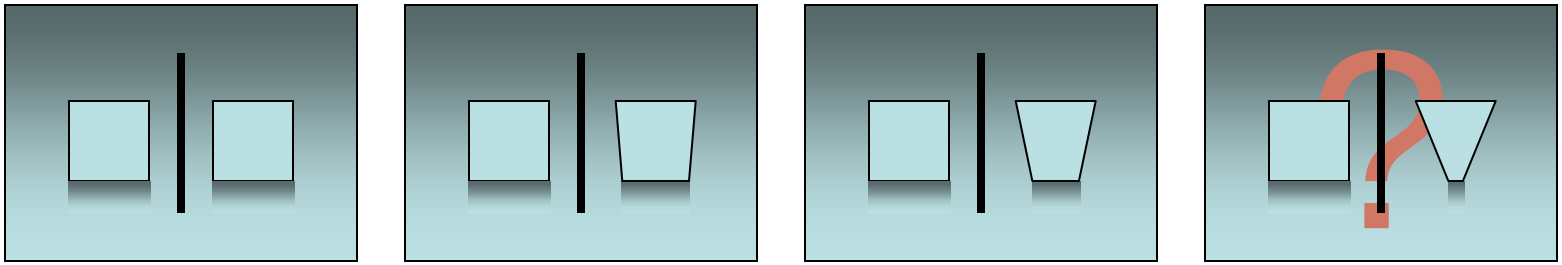
Groundtruth Labeling Ambiguity

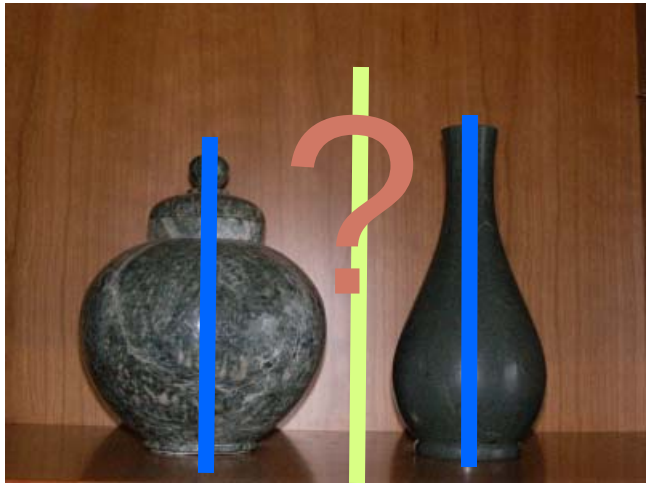
- Hierarchical reflection symmetries
  - Local versus global reflection symmetry
    - Depends on support region
    - By definition should extend to infinity
    - In practice, some tolerance is expected

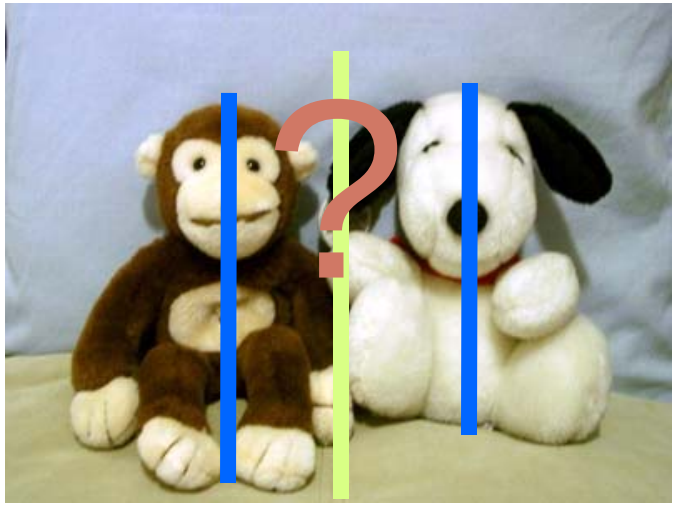


Groundtruth Labeling Ambiguity

- Shape Ambiguity







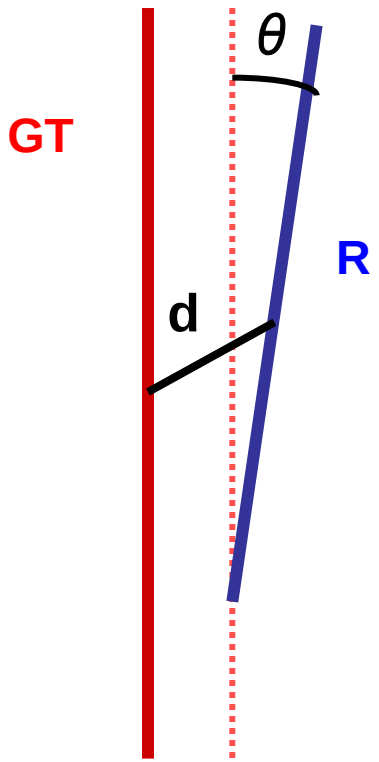
Groundtruth Labeling

- Current treatment of ambiguous groundtruth
  - Not all scales/hierarchies labeled as groundtruth
    - Subjective
    - Needs more investigation
  - Some local reflection symmetries labeled as "*dismissed groundtruth*"
    - Support region smaller than main object
    - Ignored in this round (neither TP nor FP)
    - Helps to not penalize algorithms that detect many local reflection symmetries

How to Evaluate Quantitatively

Reflection Symmetry: Evaluation Metric

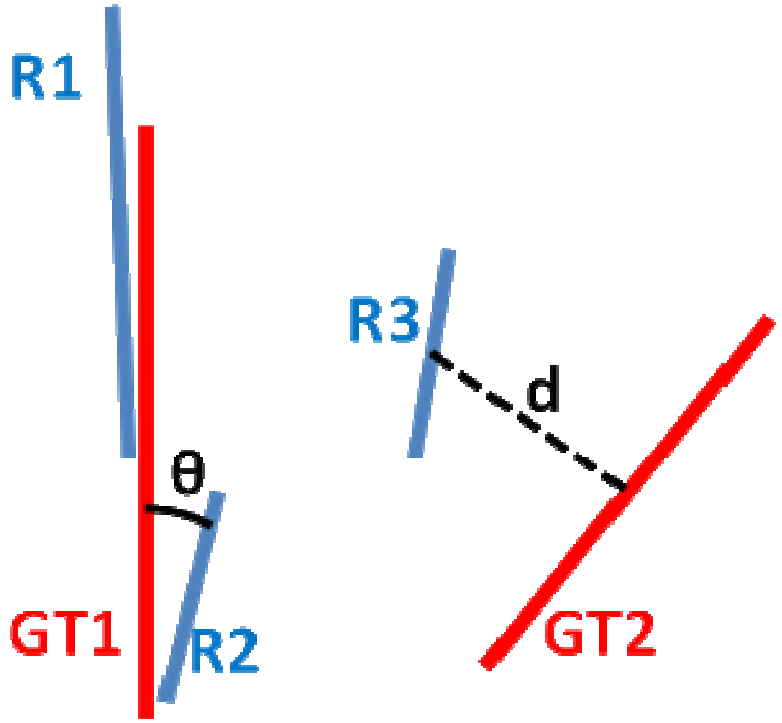
- For each detection result R measure
  - angle θ with ground-truth axis GT,
  - distance ***d*** to ground-truth axis GT (from center to center)
- Correct detection if
  - $|\theta| < 10^\circ$
  - ***d*** < 20% of *ground-truth-axis-length*.
- Multiple valid detection results (R1,R2) can be clustered
  - avoids over-counting of false positives
- Support Region not considered



Reflection Symmetry: Evaluation Metric

- Example:
  - 2 true reflection axis (GT1 and GT2 in red)
  - 3 detection results (R1, R2, R3 in blue)

  - GT=2;
  - TP=1 (R1+R2 -> *GT1*)
  - FP=1 (*R3*)
  - FN=1 (*GT2*)



Reflection Symmetry: Evaluation Score

- We use ***precision*** and ***recall*** to judge algorithm performance
- In terms of Type I and Type II errors

Precision = TP / (TP + FP)

Recall = TP / (TP + FN)

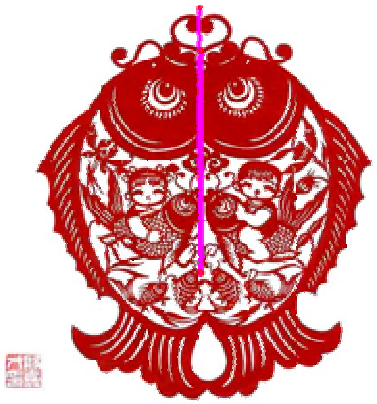
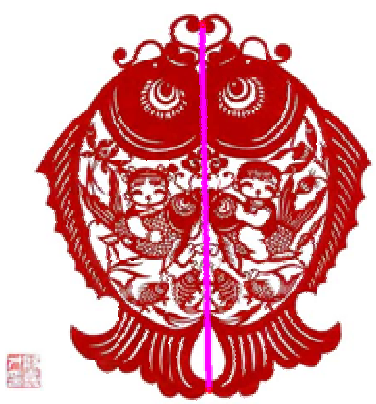
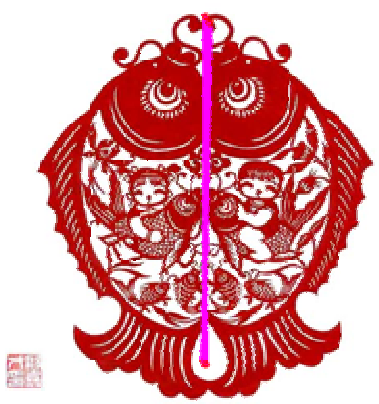
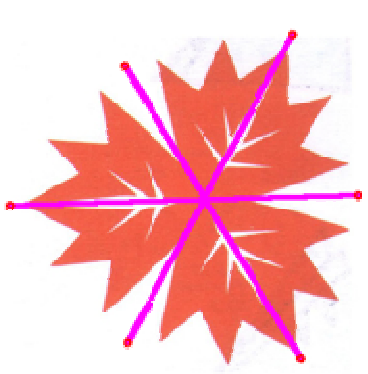
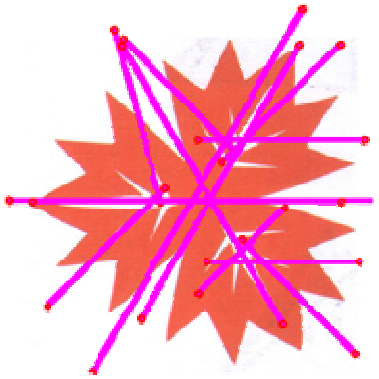
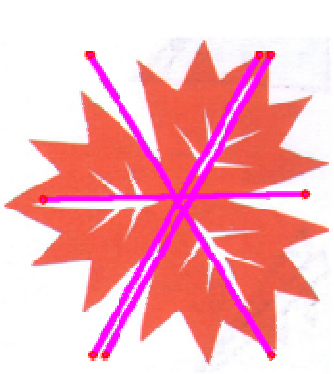
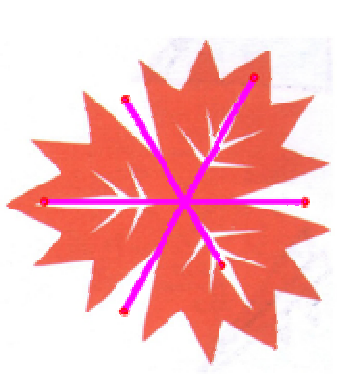
TP = True Positives,
FN = False Negatives
FP = False Positives

Reflection Symmetry: Results & Comparison

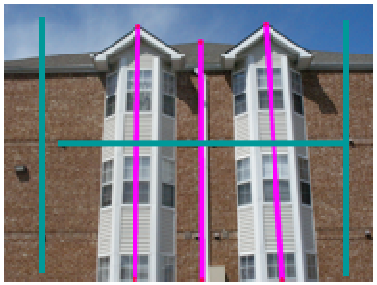
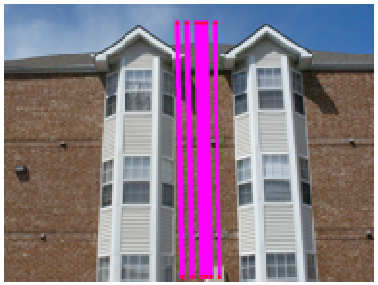
Reflection Symmetry: Results & Comparison

- Algorithms:
  - **Mo and Draper**
  - **Kondra and Petrosino**
  - **Gareth Loy and Jan-Olof Eklundh** (baseline)

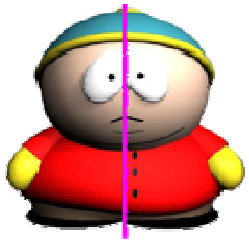
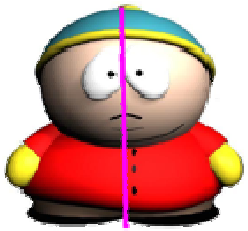
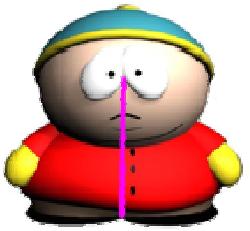
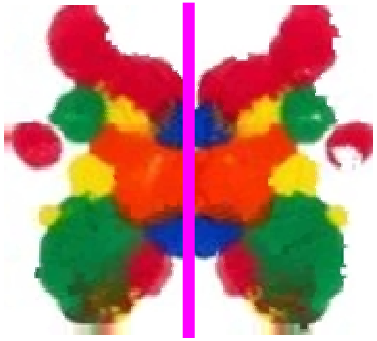
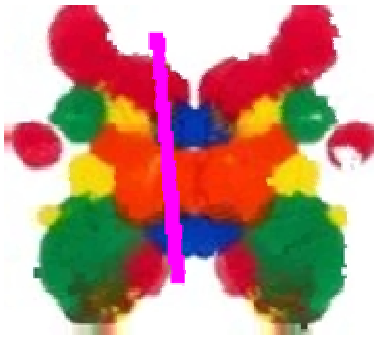
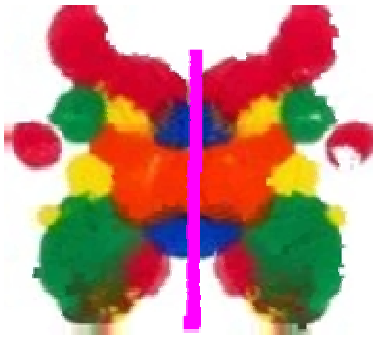
Sample Results: Synthetic Images

Groundtruth	Kondra and Petrosino	Mo and Draper	Loy and Eklundh
			
			

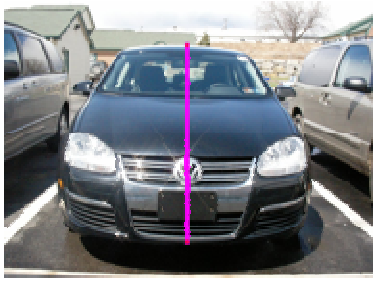
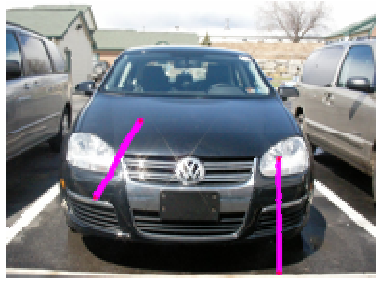
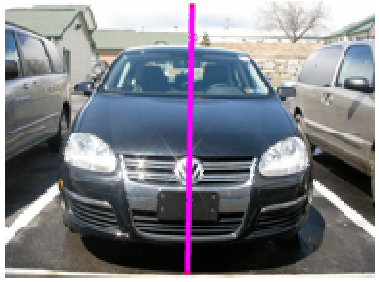
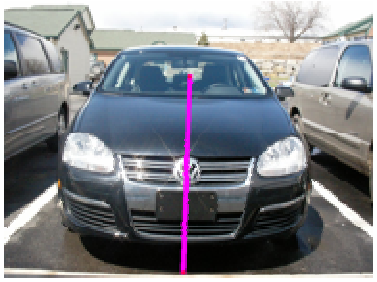
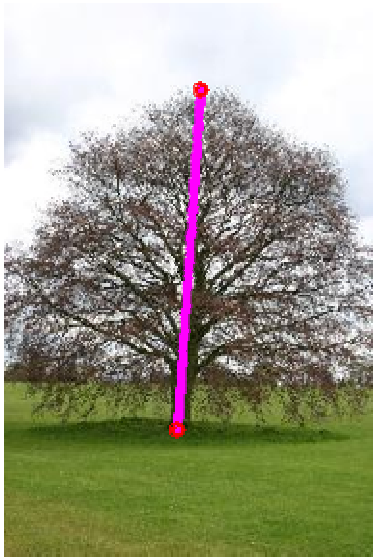
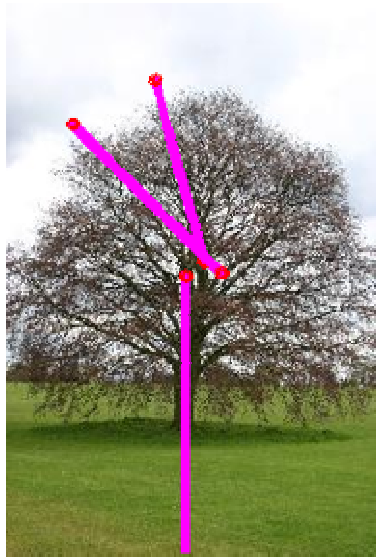
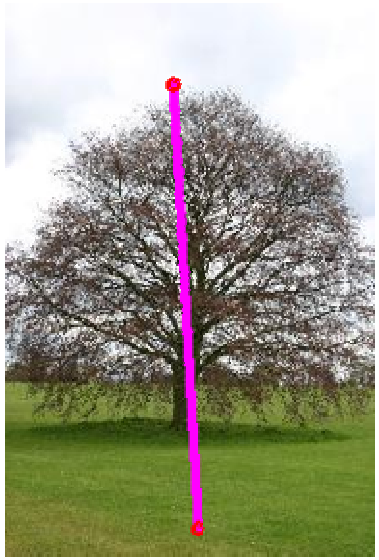
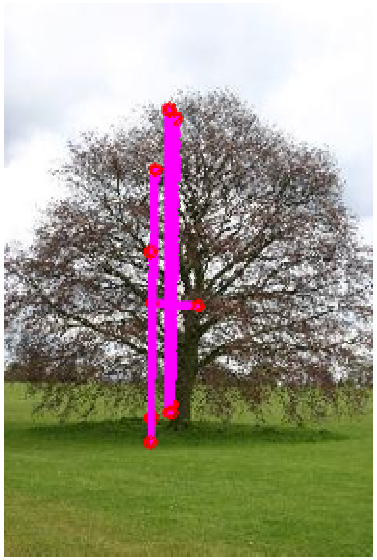
Sample Results: Real Images

Groundtruth	Kondra and Petrosino	Mo and Draper	Loy and Eklundh
			
			

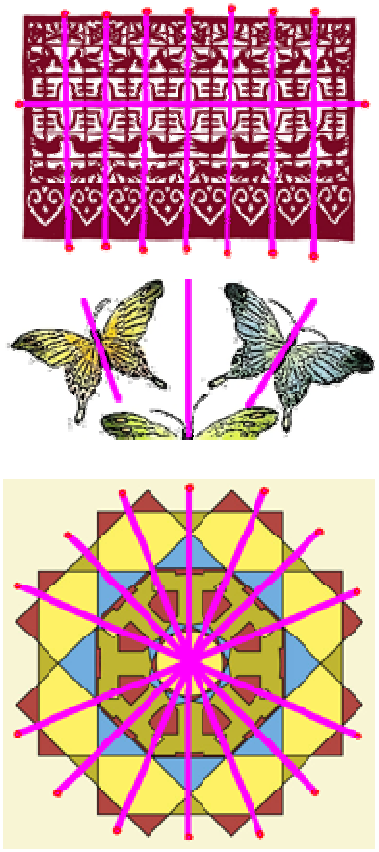
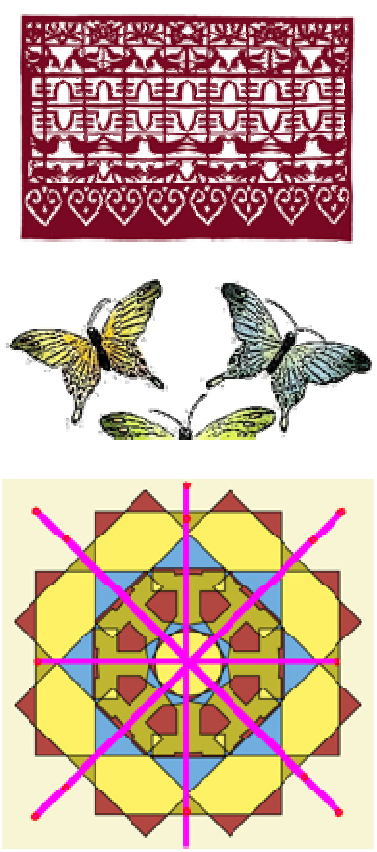
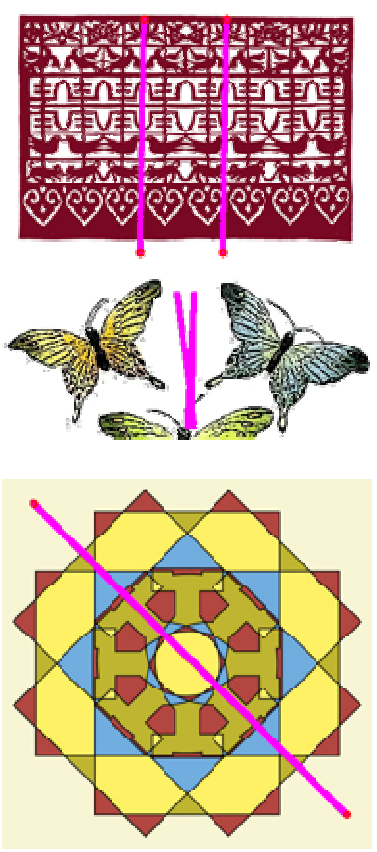
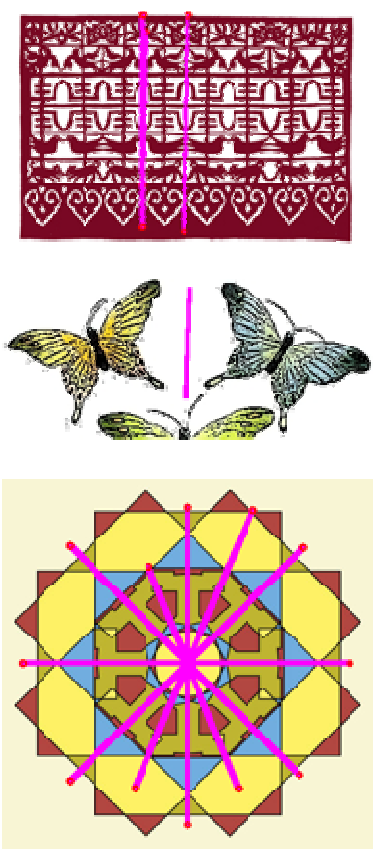
Sample Results: Single Reflection Axis & Synthetic Images

Groundtruth	Kondra and Petrosino	Mo and Draper	Loy and Eklundh
			
			

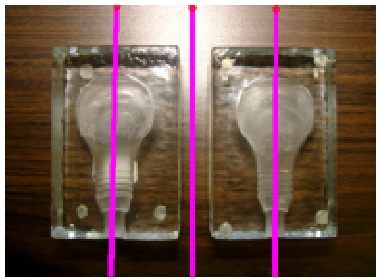
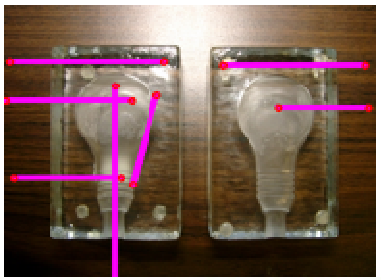
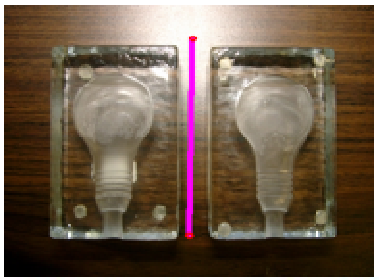
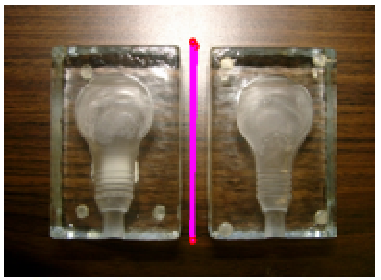
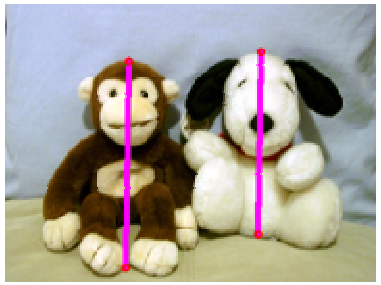
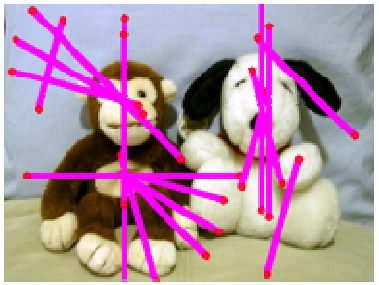
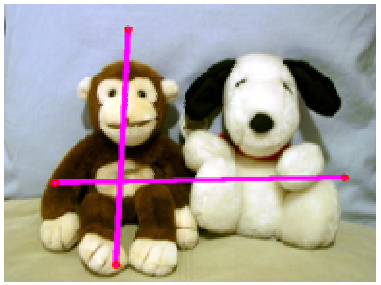
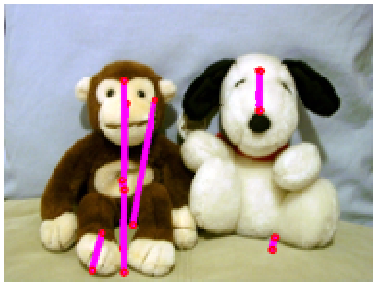
Sample Results: Single Reflection Axis & Synthetic Images

Groundtruth	Kondra and Petrosino	Mo and Draper	Loy and Eklundh
			
			

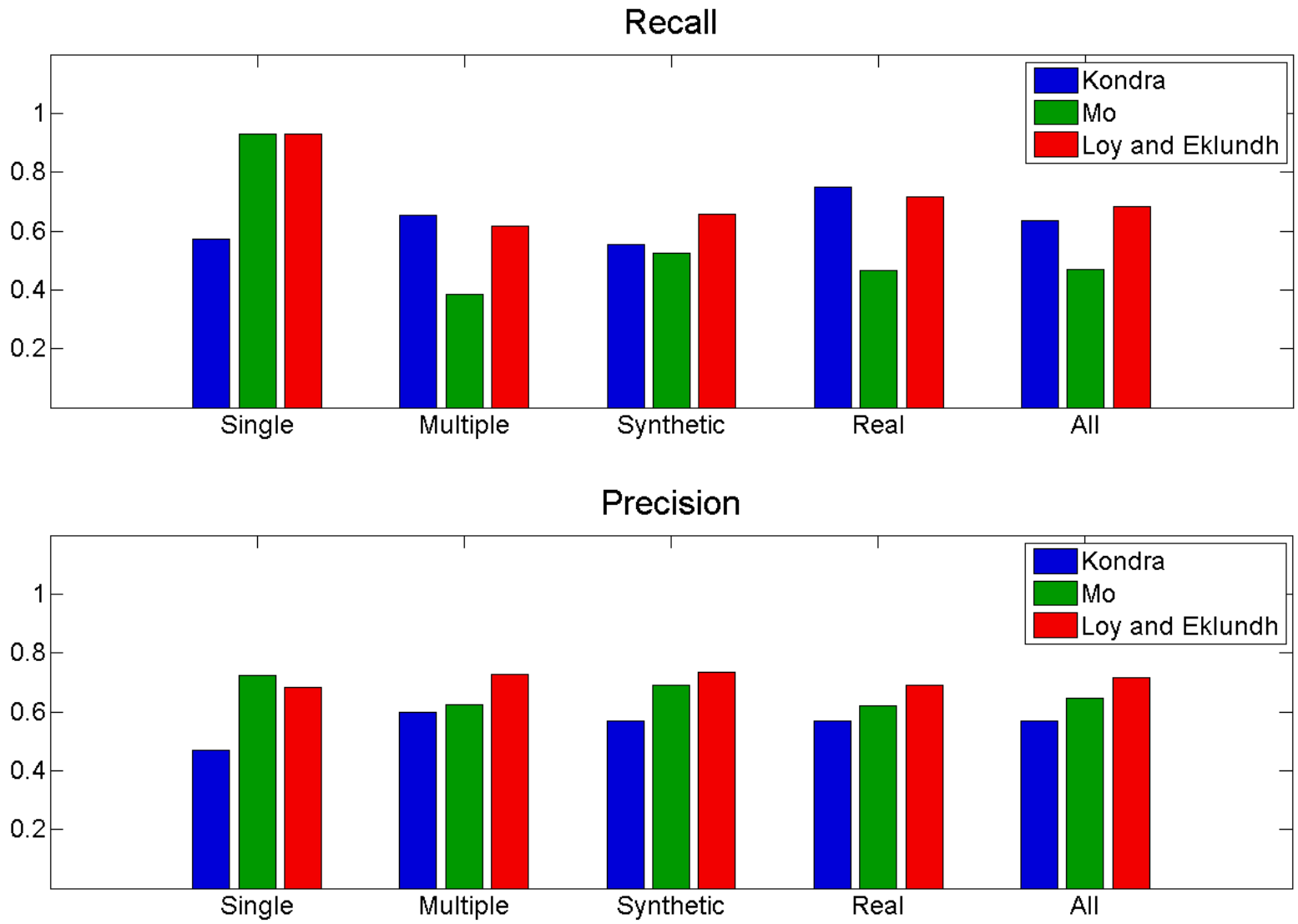
Sample Results: Multiple Reflection Axis & Synthetic Images

Groundtruth	Kondra and Petrosino	Mo and Draper	Loy and Eklundh
			

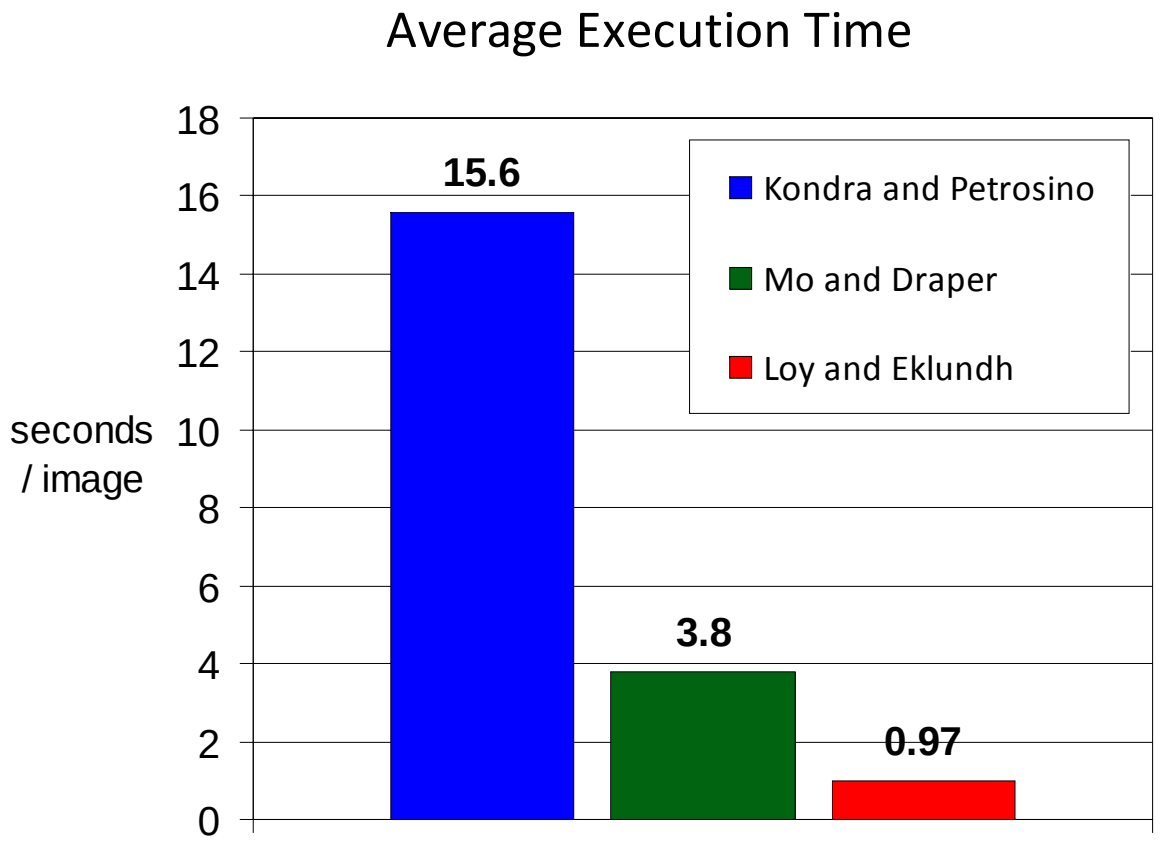
Sample Results: Multiple Reflection Axis & Real Images

Groundtruth	Kondra and Petrosino	Mo and Draper	Loy and Eklundh
			
			
			

Reflection Symmetry: Performance by Category



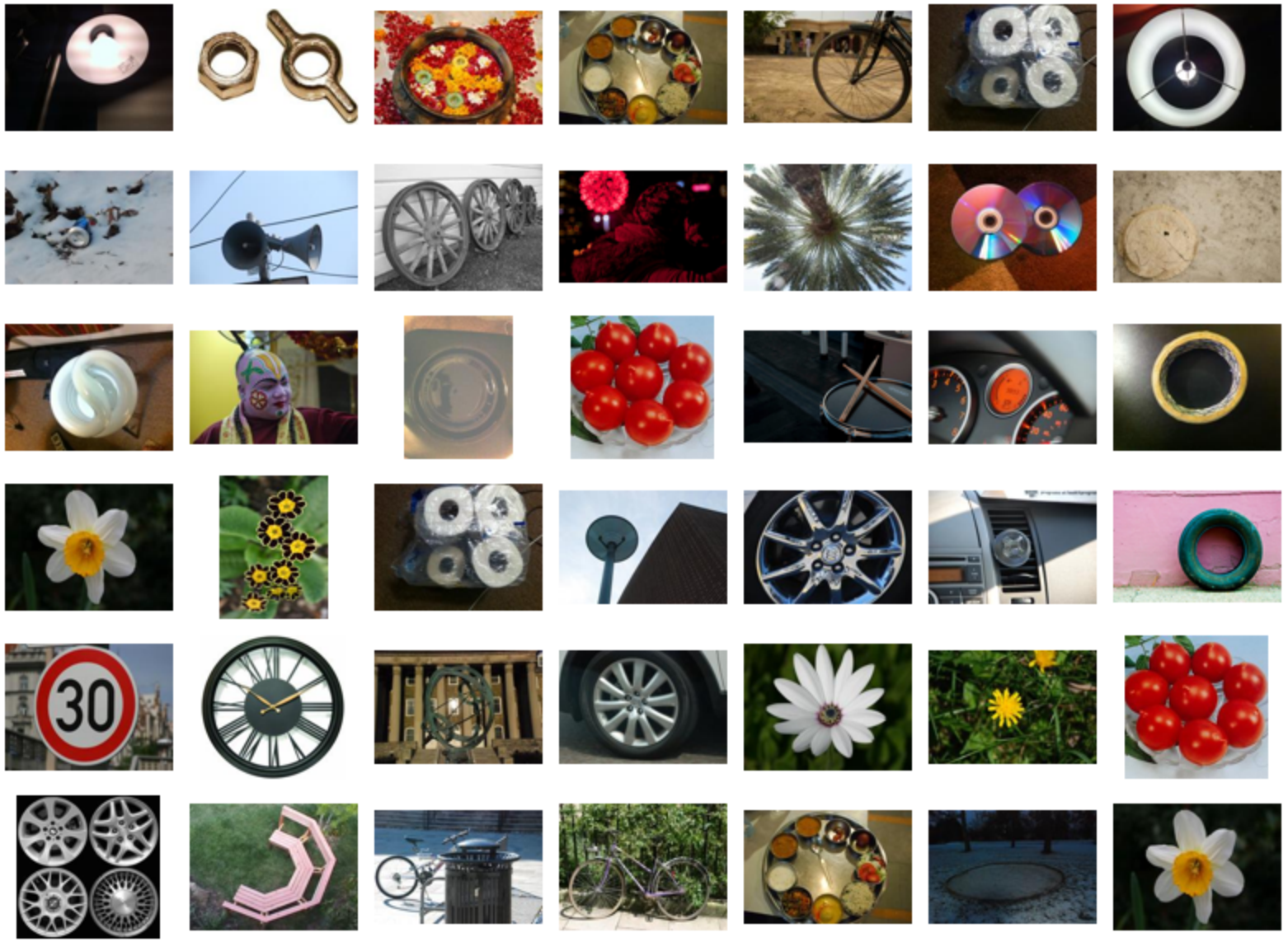
Reflection Symmetry: Computational Performance



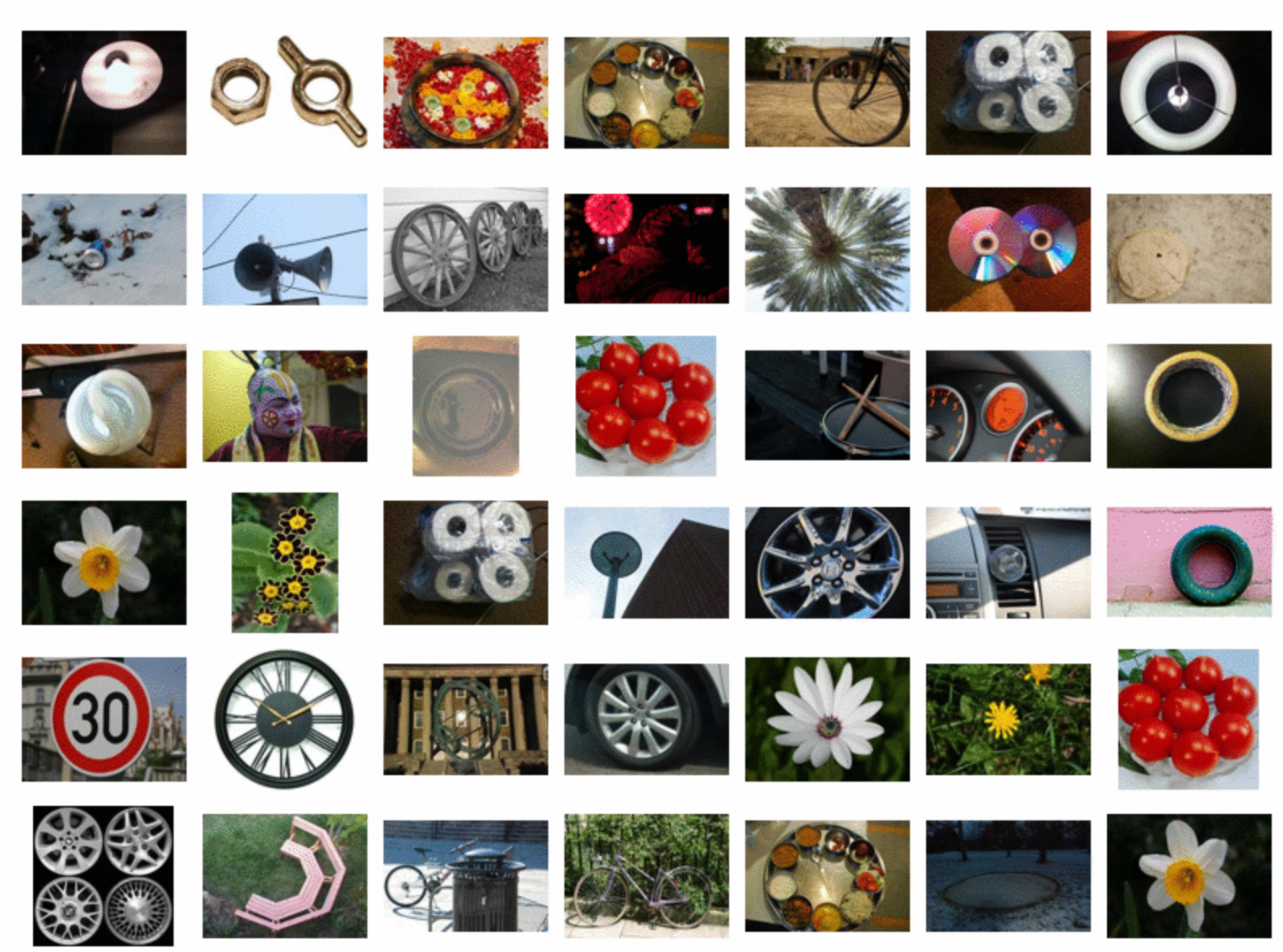
performed on a Windows Vista 64bit machine with an i7, 2.67G cpu (8 core), 6GB ram and used Matlab R2008b

Rotation Symmetry

Rotation Symmetry - Dataset

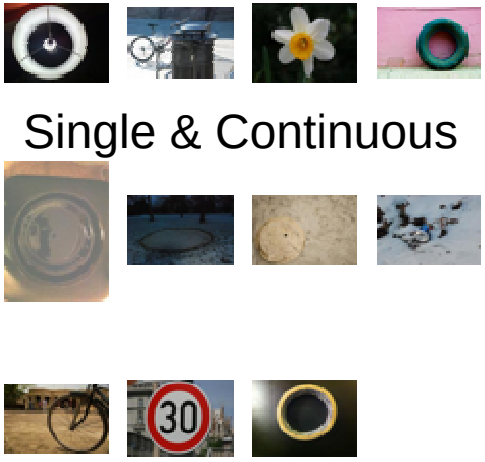


Rotation Symmetry - Dataset

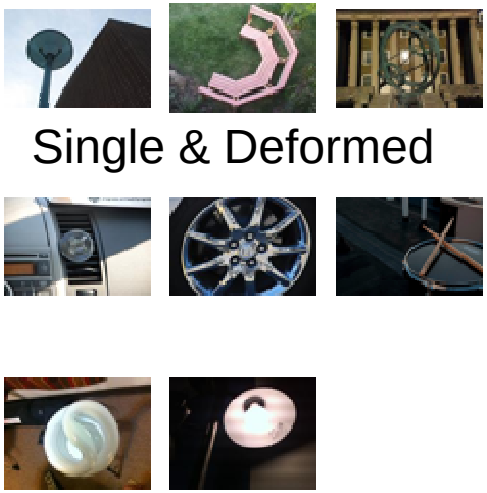


Rotation Symmetry - Dataset

Single & Discrete



Single & Continuous



Single & Deformed

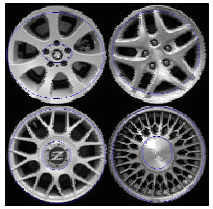
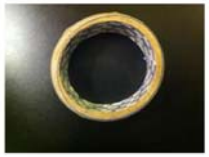
Multiple & Discrete

Single & Continuous

Multiple & Deformed

Rotation Symmetry: Test Categories

- Number of Images: 40
- Avg. image size: (200x180)

	Single			Multiple			**Total**	
Discrete		**#Imgs**	**#Syms**		**#Imgs**	**#Syms**	**#Imgs**	**#Syms**
		11	**11**		**3**	**16**	**14**	**27**
Continuous		**10**	**10**		**5**	**25**	**15**	**35**
Deformed		**7**	**7**		**4**	**12**	**11**	**19**
Total		**28**	**28**		**12**	**53**	**40**	**81**

Rotation Symmetry: Groundtruth Labeling

– Symmetry center
  - Object Center (x,y)
  - As perceived by a human annotator

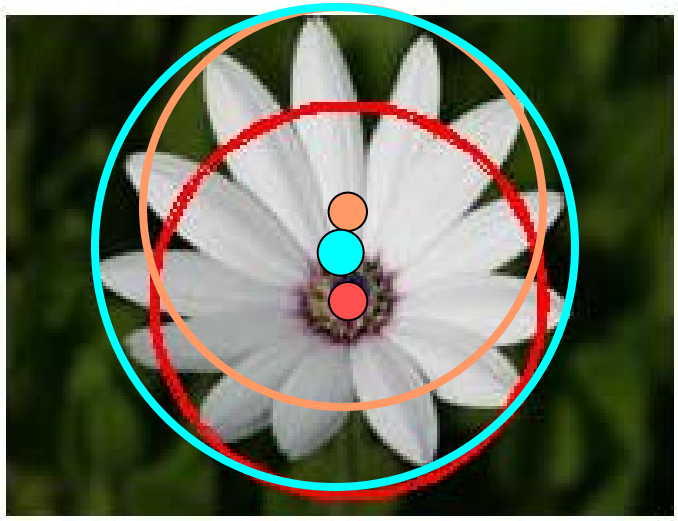
– Support Region
  - Maximum, encompassing ellipse
  - Length of major & minor axis (a,b)
  - Orientation to x-axis (θ)

Rotation Symmetry: Groundtruth Labeling

- Groundtruth labeling can be ambiguous
  - What constitutes a valid groundtruth?
    - Application/Intend
    - Individual Annotator
- Examples
  - Where is the symmetry center?
  - What is the radius?
  - M symmetries at the same place?
  - A symmetry has to recover a real object?

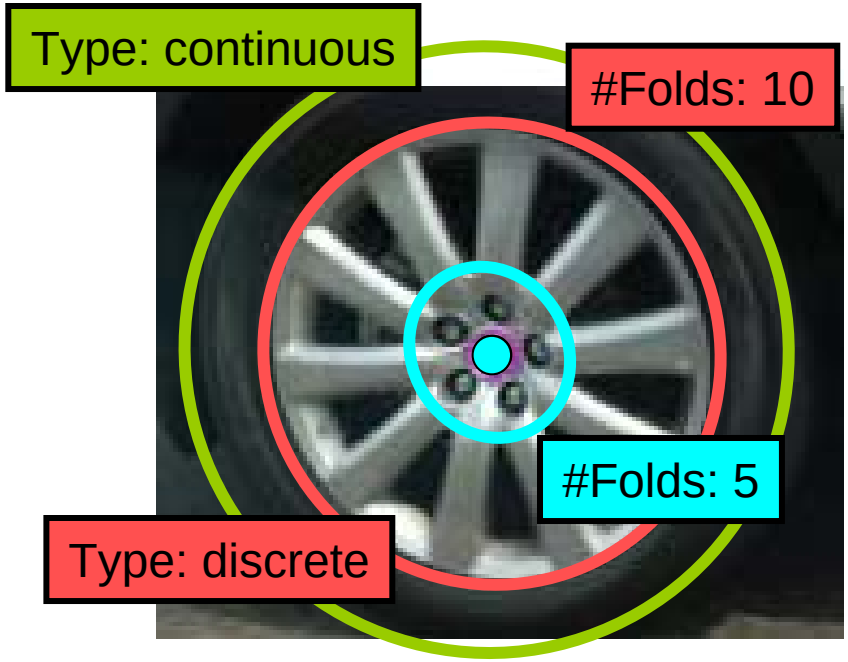
Rotation Symmetry: Ambiguous Groundtruth

- Where is the symmetry center?
  - Circular rot symmetries: Unique!
  - Distorted symmetries (affine or perspective): Ambiguous!



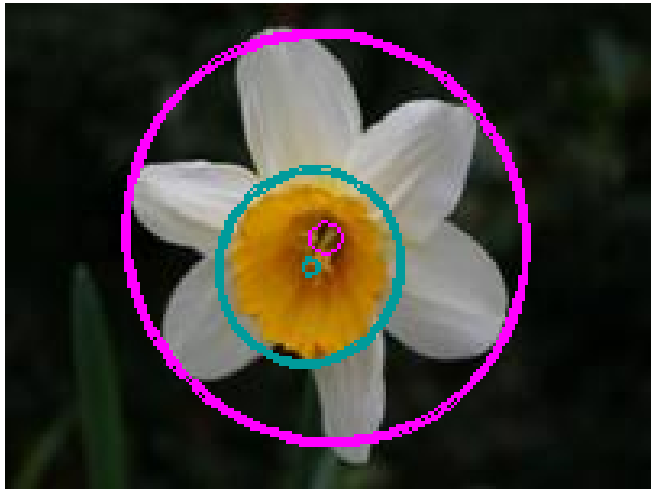
Rotation Symmetry: Ambiguous Groundtruth

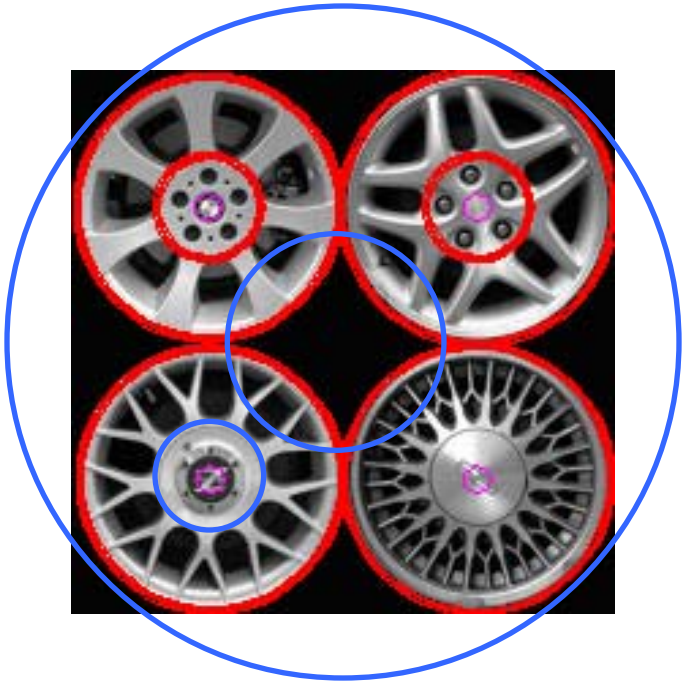
- What is the radius of a rotation symmetry?
- Can we have multiple radii per center?
- How to differentiate multiple symmetries at same center?
  - Type of symmetry
  - Number of folds



Rotation Symmetry: Ambiguous Groundtruth

- Symmetry Hierarchy
  - Within object
  - Single object
  - Among objects
- What is an object?



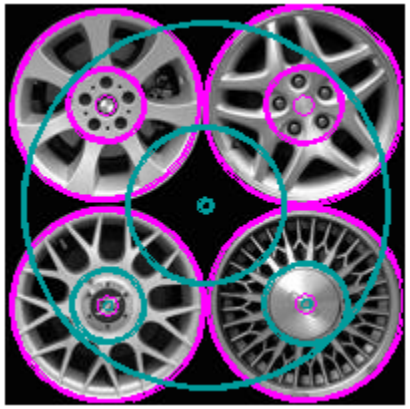


Rotation Symmetry: Groundtruth Labeling (contd.)

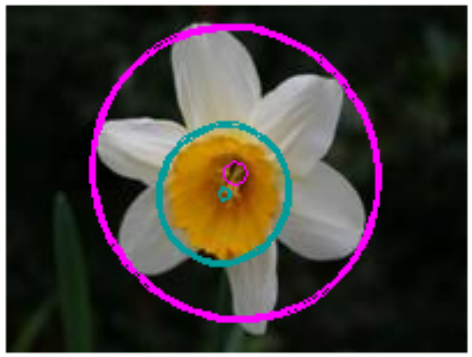
What do we do?

- Annotate ambiguous symmetries to be discounted for
  - False Positives
  - Groundtruth

- Sample Groundtruth
  - Valid Groundtruth (magenta)
  - Discounted (cyan)



Different center than real objects

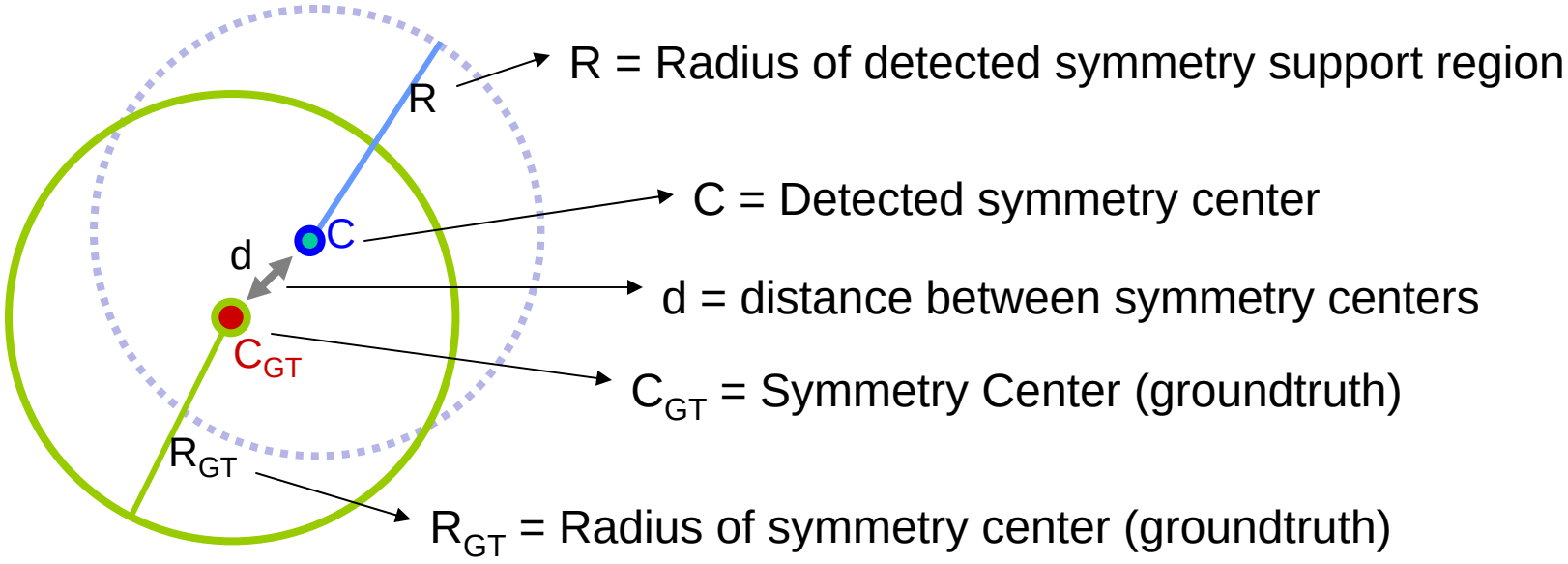


Inner symmetry not a discrete symmetry

Same center as real object, support region too small

Rotation Symmetry: Evaluation Metric

Rotation Symmetry: Evaluation Metric



Correct detection if

- Distance between detected center (C) and groundtruth center (C_{GT}) below some threshold (depended on GT radius)
- Radius (R) within some bounds of GT radius (R_{GT})

Rotation Symmetry: Evaluation Score

- We use ***precision*** and ***recall*** to judge algorithm performance
- In terms of Type I and Type II errors

Precision = TP / (TP + FP)

Recall = TP / (TP + FN)

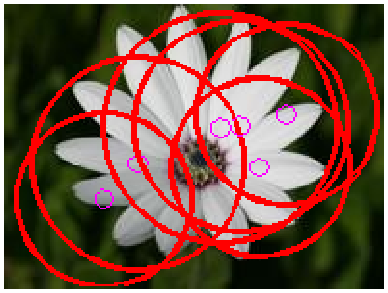
TP = True Positives,
FN = False Negatives
FP = False Positives

Results and Comparison

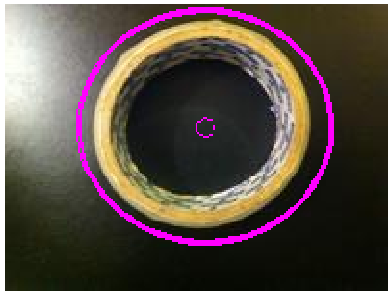
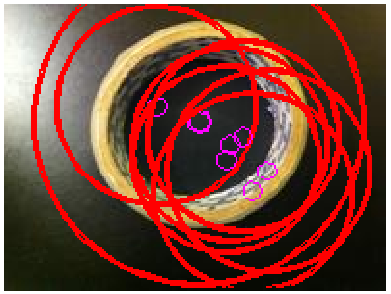
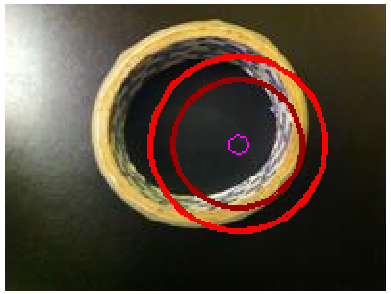
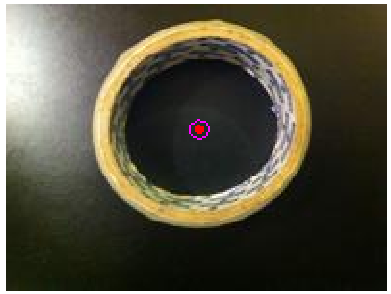
Reflection Symmetry: Results & Comparison

- Algorithms:
  - **Kim, Cho and Lee**
  - **Kondra and Petrosino**
  - **Gareth Loy and Jan-Olof Eklundh** (baseline)

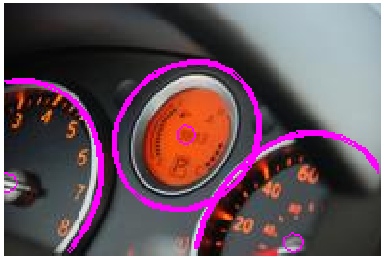
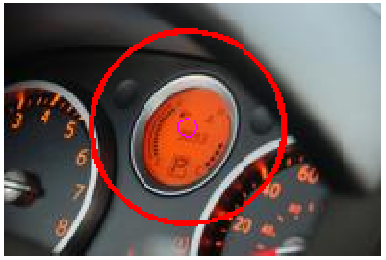
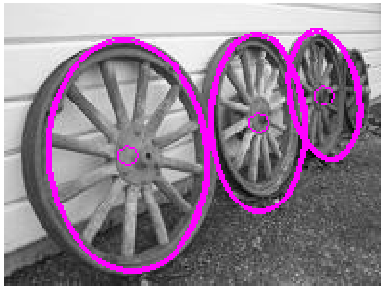
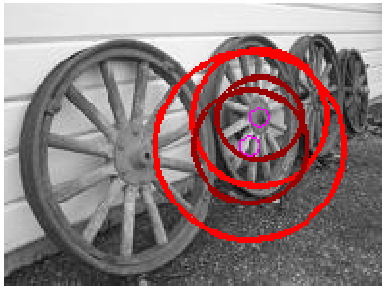
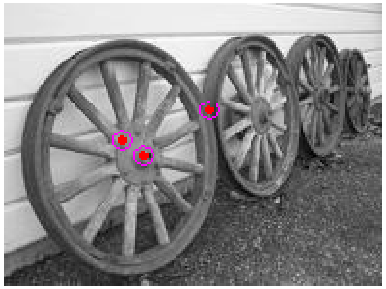
Rotation Symmetry: Comparison

Groundtruth	Kondra and Petrosino	Kim, Cho and Lee	Loy and Eklundh
GT: 1 	TP: 1, FP: 1 	TP: 1, FP: 0 	TP: 1, FP: 0 
GT: 1 	TP: 0, FP: 6 	TP: 1, FP: 0 	TP: 1, FP: 0 

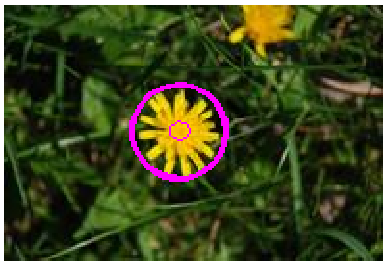
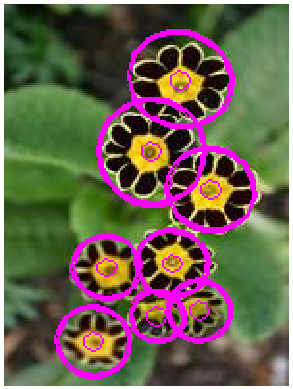
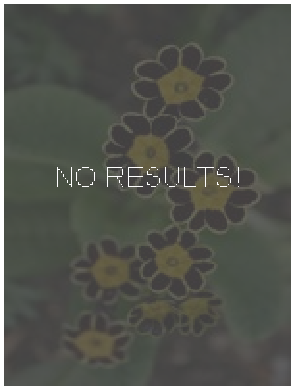
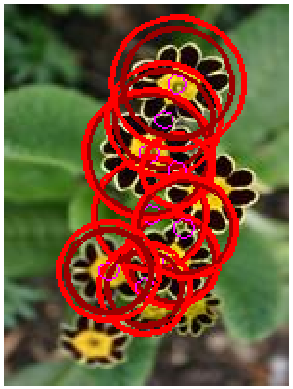
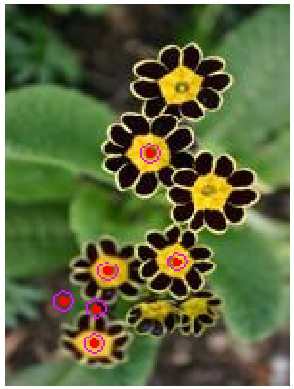
Rotation Symmetry: Comparison

Groundtruth	Kondra and Petrosino	Kim, Cho and Lee	Loy and Eklundh
GT: 1 	TP: 1, FP: 1 	TP: 0, FP: 0 	TP: 1, FP: 0 
GT: 1 	TP: 1, FP: 6 	TP: 0, FP: 1 	TP: 1, FP: 0 

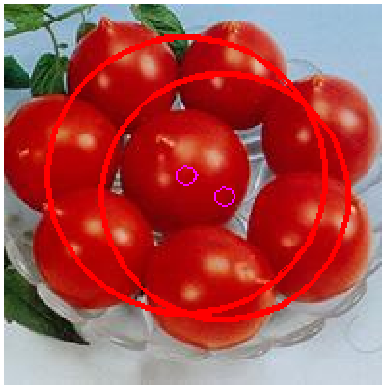
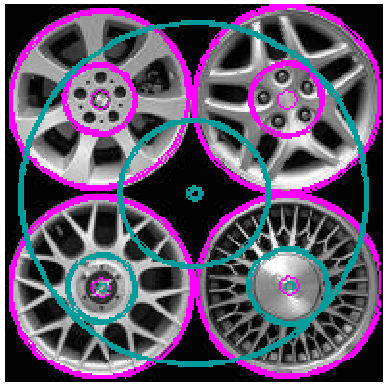
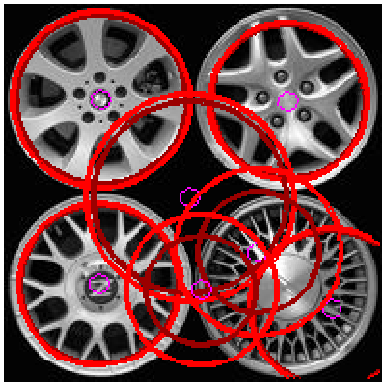
Rotation Symmetry: Comparison

Groundtruth	Kondra and Petrosino	Kim, Cho and Lee	Loy and Eklundh
GT: 3 	TP: 1, FP: 3 	TP: 0, FP: 0 	TP: 2, FP: 0 
GT: 3 	TP: 0, FP: 3 	TP: 1, FP: 1 	TP: ', FP: 1 

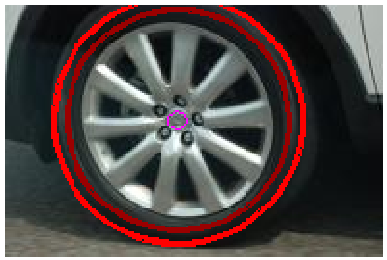
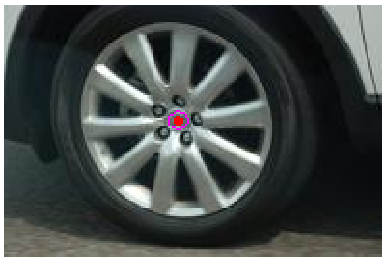
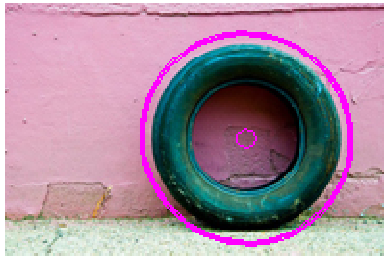
Rotation Symmetry: Single vs. Multiple Symmetries

Groundtruth	Kondra and Petrosino	Kim, Cho and Lee	Loy and Eklundh
GT: 1 	TP: 1, FP: 1 	TP: 1, FP: 0 	TP: 1, FP: 0 
GT: 8 	TP: 0, FP: 0 	TP: 4, FP: 5 	TP: 4, FP: 2 

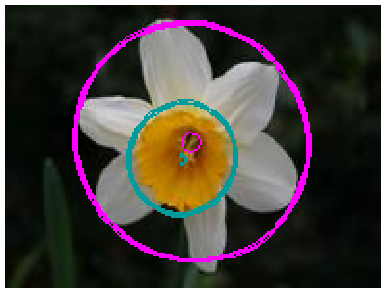
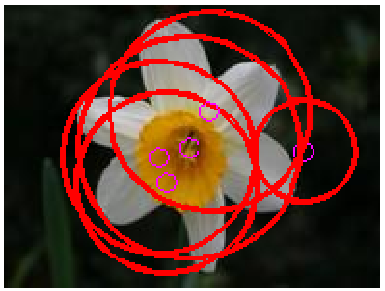
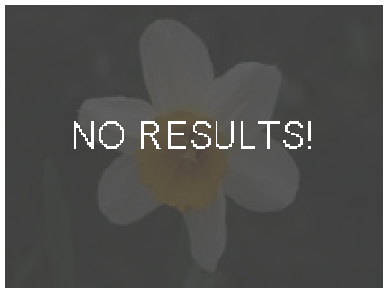
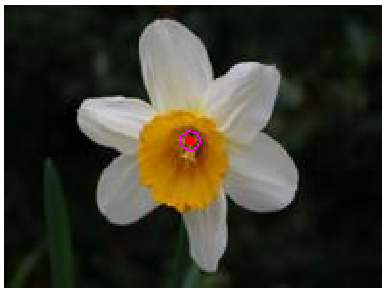
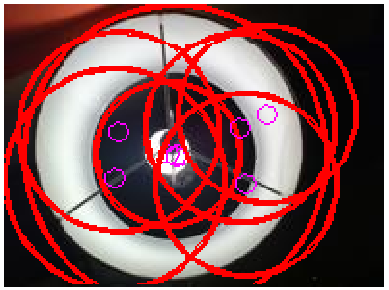
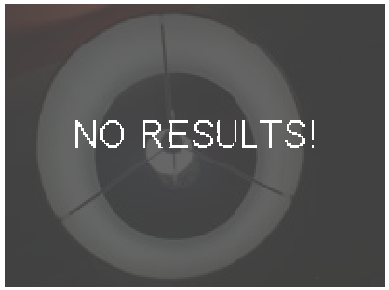
Rotation Symmetry: Single vs. Multiple Symmetries

Groundtruth	Kondra and Petrosino	Kim, Cho and Lee	Loy and Eklundh
GT: 1 	TP: 1, FP: 0.5 	TP: 0, FP: 0 	TP: 0, FP: 0.5 
GT: 3 	TP: 1, FP: 0 	TP: 3, FP: 3 	TP: 2, FP: 0 

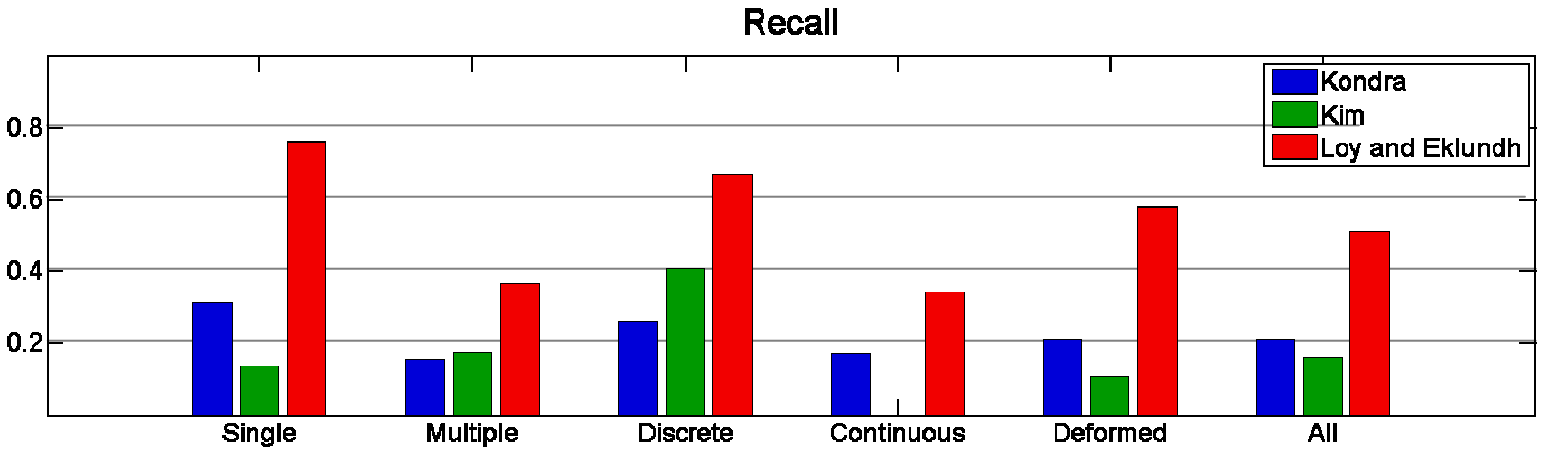
Rotation Symmetry: Discrete vs. Continuous

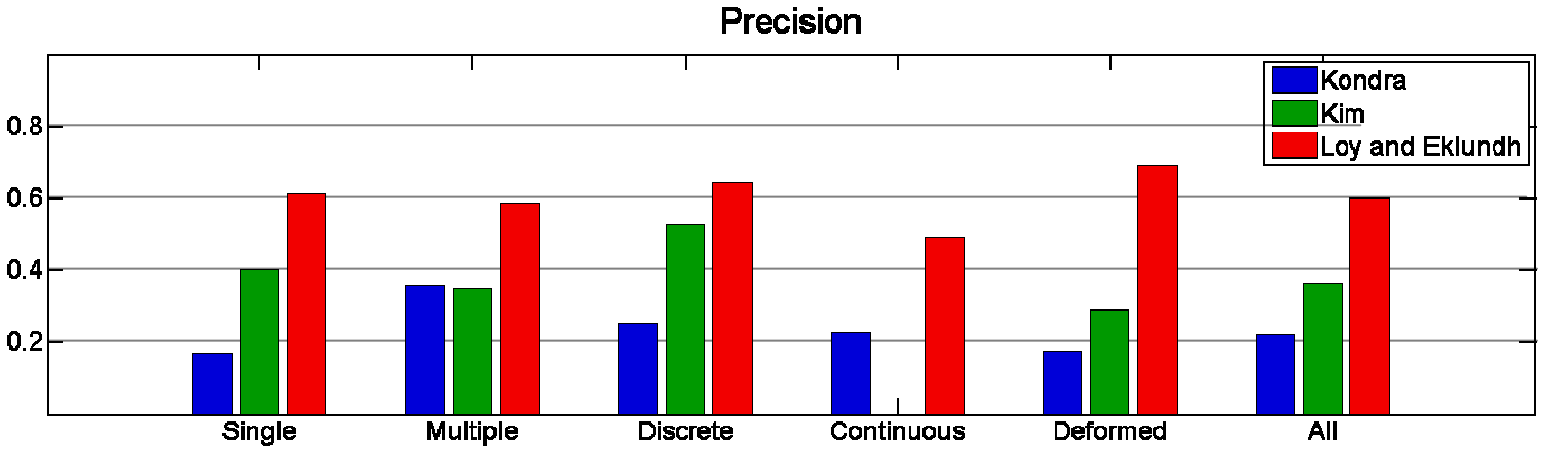
Groundtruth	Kondra and Petrosino	Kim, Cho and Lee	Loy and Eklundh
GT: 1 	TP: 0, FP: 0 	TP: 1, FP: 3 	TP: 1, FP: 0 
GT: 1 	TP: 0, FP: 1 	TP: 0, FP: 0 	TP: 1, FP: 0 

Rotation Symmetry: Discrete vs. Continuous

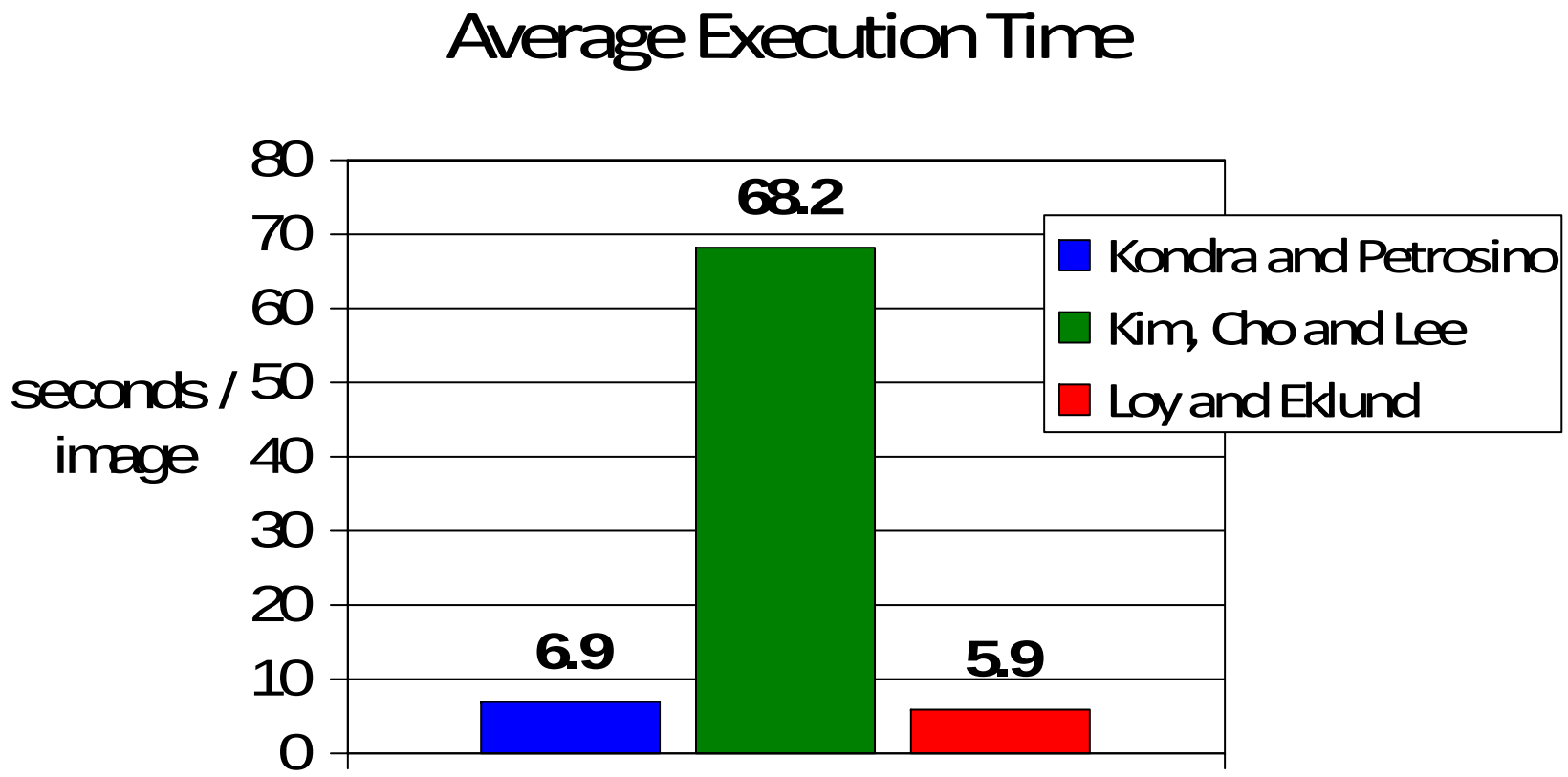
Groundtruth	Kondra and Petrosino	Kim, Cho and Lee	Loy and Eklundh
GT: 1 	TP: 1, FP: 4 	TP: 0, FP: 0 	TP: 1, FP: 0 
GT: 1 	TP: 1, FP: 5 	TP: 0, FP: 0 	TP: 1, FP: 0 

Rotation Symmetry: Overall Results (Recall)





Rotation Symmetry: Quantitative Results



Other Observations

- Kondra and Peterson
  - Sensitive to affine distortion
  - Many false positives
  - 12 test images produced no results
- Kim, Cho and Lee
  - Difficulties with smooth contours, low contrast (SIFT keys to blame?)
  - 6 test images produced abnormal program termination
  - 18 test images produced no results

The End