ROBUST ELLIPSE DETECTION VIA ARC SEGMENTATION AND CLASSIFICATION

Authors: ***Huixu Dong, Dilip K. Prasad, I-Ming Chen, Fellow, IEEE***

presented by
Huixu Dong
PhD Candidate

Robotics Research Center
Nanyang Technological University
September 18th ,2017

Content

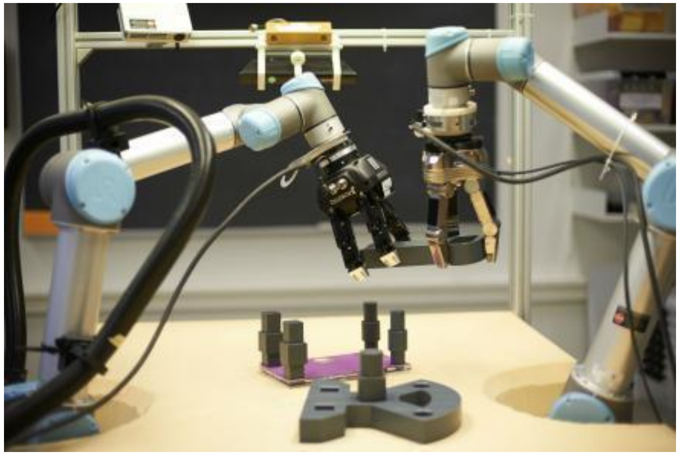
Content

Introduction

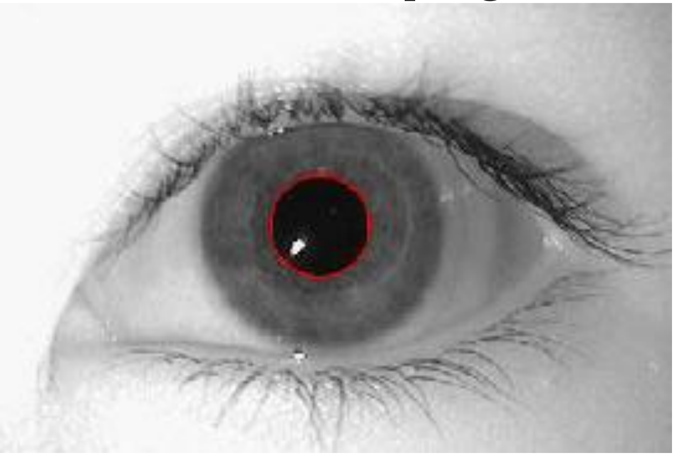
Motivation

Traffic sign recognition

Satellite coupling



Assembling mechanical parts



Medical diagnosis

Two main challenges for ellipse detection

- Low accuracy of ellipse detection
- High computational cost

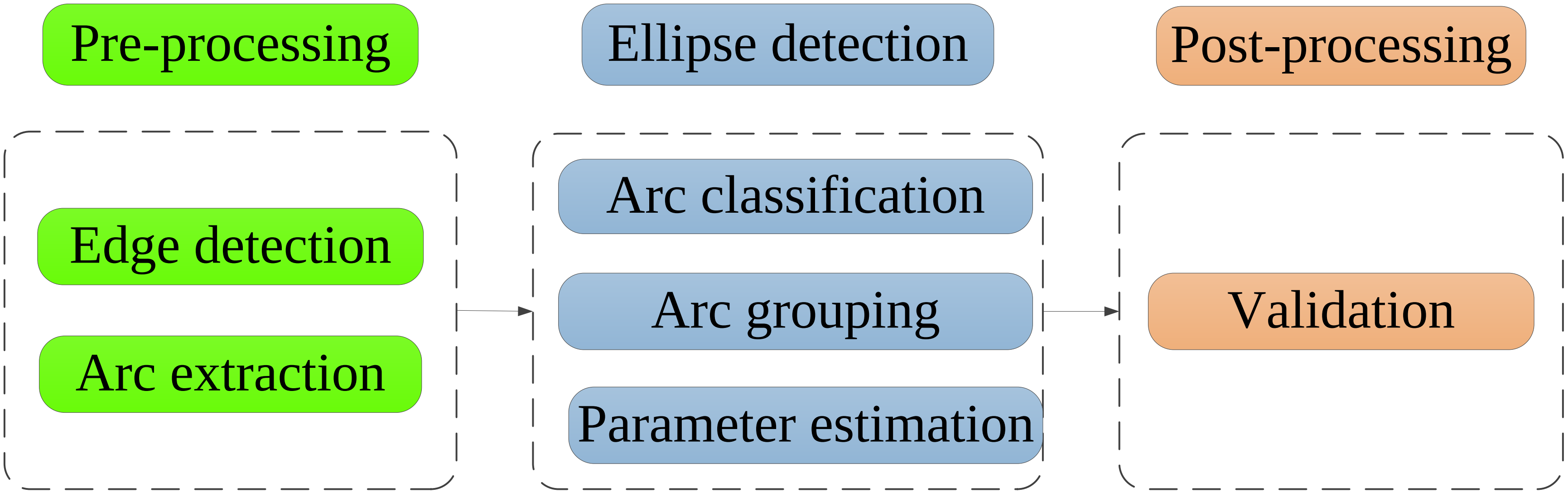
Introduction

Existing methods

Classifications	HT-based methods	Arc accumulation techniques	Algebraic or geometric methods
Representative references	R. O. Duda, et al,1972 N. Kiryati ,et.al,1991 A. A. Sewisy,et al,2005 S.-C. Zhang,et al, 2007	Q. Ji,et al,1999 L. Libuda, et al,2007 D. K. Prasad et al,2013 T. Lu,et al,2015	C. Liu,et al, 2013 M. Fornaciari,et al,2014 S. Mulleti,et al,2016 Q. Jia,et al,2017
Advantages	Fitting ellipses with a small bias	High detection accuracy	High detection accuracy; High computational time
Disadvantages	The computation times	The computational complexity	Occluded/overlapping ellipses

Methodology

Methodology



Methodology

Edge detection and arc extraction


Original image

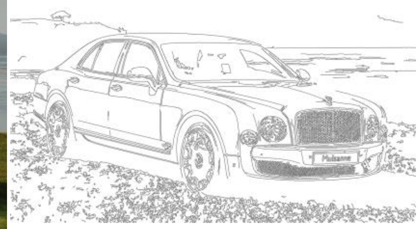

Edge image


Image with (+) gradient

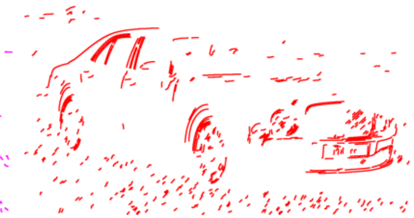
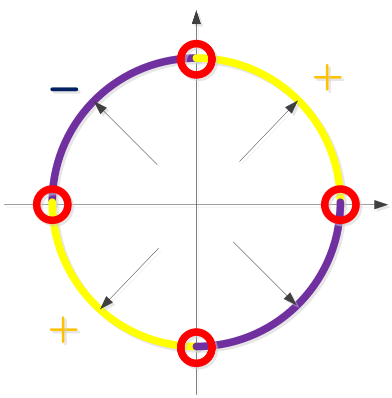
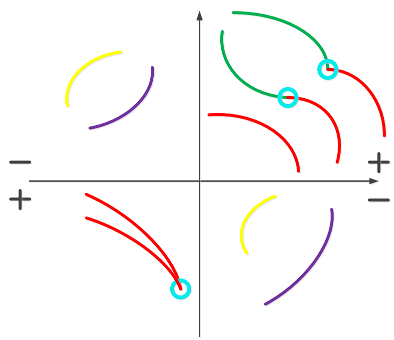


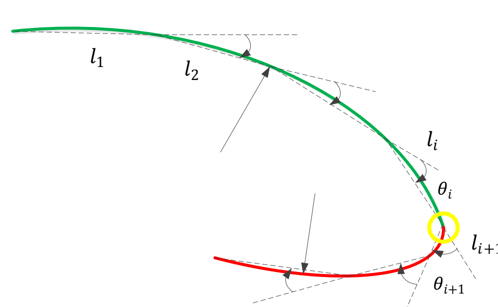
Image with (-) gradient

The gradient sign of image:

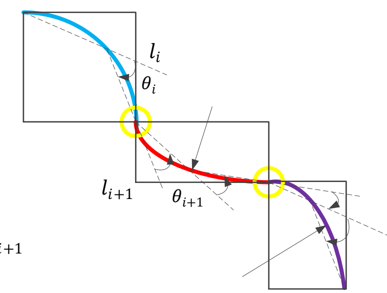
$$X(p_i) = sign(\tan(\eta_i)) = sign(dx) \cdot sign(dy)$$







A-Turning corner



B-Inflexion point

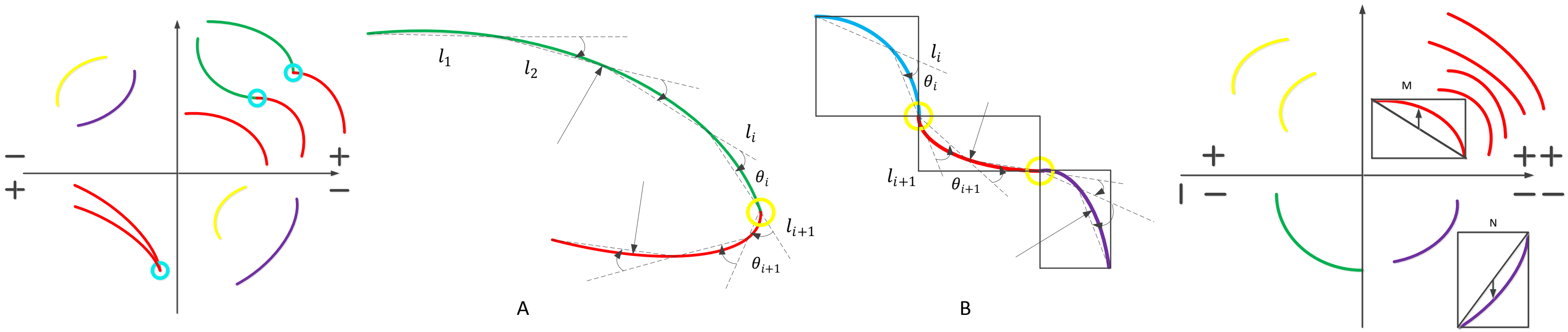
The arc is fitted by a series of line segments (l_i, θ_i). The sharp points are identified through the following geometric constraint:

$$|\theta_i - \theta_{i+1}| > Thre_a$$

NANYANG TECHNOLOGICAL UNIVERSITY

Methodology

Arc classification



The arc convexity-concavity

$$\Theta(a) = \begin{cases} +, \boldsymbol{\delta} > 0; \\ -, \boldsymbol{\delta} < 0. \end{cases}$$

Therefore, based on the functions X and Θ,each arc a can be classed to the corresponding quadrant by the function Φ:

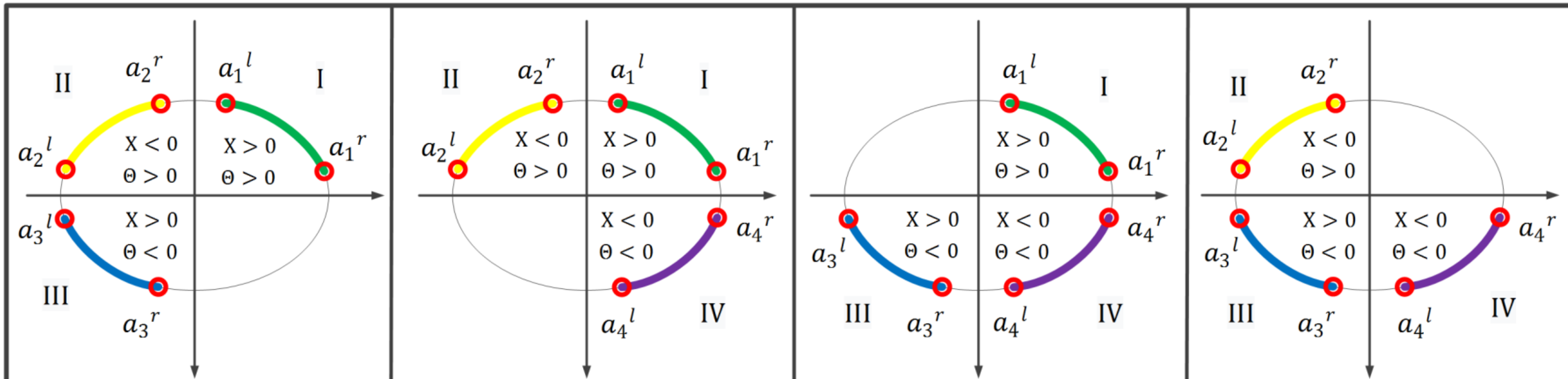
$$\Phi(a) = \begin{cases} \text{I}, & \langle\, (\mathrm{X}(p_i), \Theta(a))\rangle = \langle +, + \rangle \\ \text{II}, & \langle\, (\mathrm{X}(p_i), \Theta(a))\rangle = \langle -, + \rangle \\ \text{III}, & \langle\, (\mathrm{X}(p_i), \Theta(a))\rangle = \langle +, - \rangle \\ \text{IV}, & \langle\, (\mathrm{X}(p_i), \Theta(a))\rangle = \langle -, - \rangle \end{cases}$$

Methodology

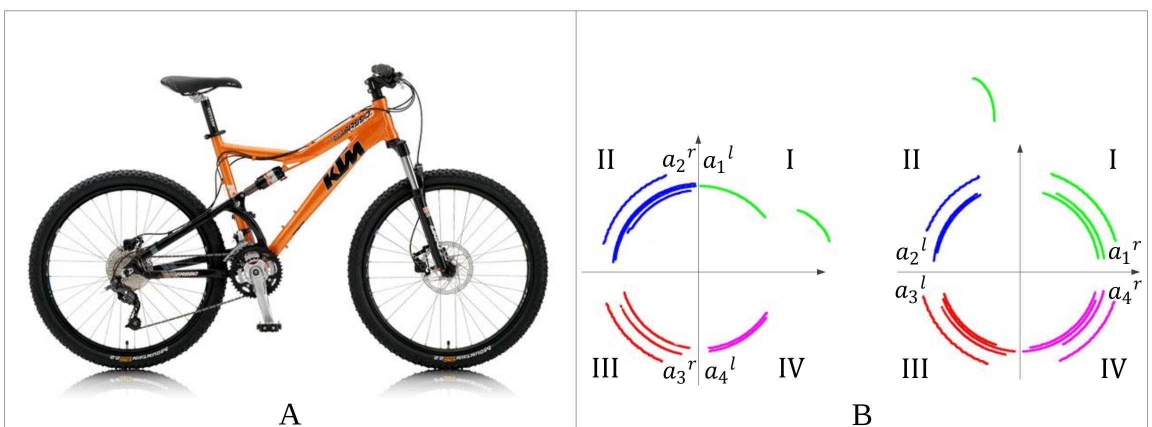
Arc grouping

The arc sets consisting of an ellipse must satisfy the two following constrains:

- The relative position
- The same ellipse centre.



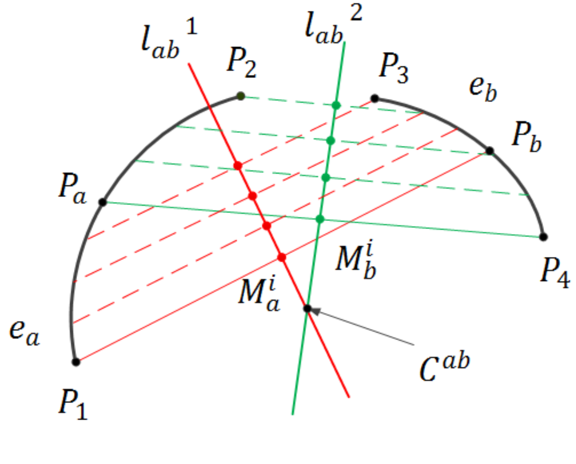
$a_2^r(x) < a_1^l(x)$ $a_2^l(y) < a_3^l(y)$	$a_1^l(x) > a_2^r(x)$ $a_1^r(y) < a_4^r(y)$	$a_4^l(x) > a_3^r(x)$ $a_4^r(y) > a_1^r(y)$	$a_3^r(x) < a_4^l(x)$ $a_3^l(y) > a_2^l(y)$

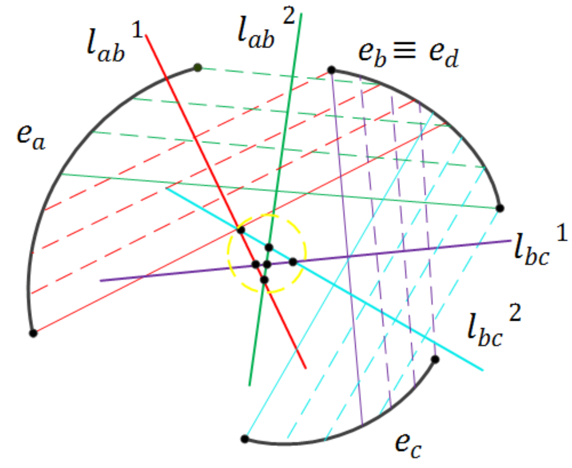


NANYANG TECHNOLOGICAL UNIVERSITY

Methodology

Parameter estimation(Accumulation method)





Determination of ellipse centre (Parallel chord method):

$$C.x = \frac{M_b.y - t_2 \times M_b.x - M_a.y + t_1 \times M_a.x}{t_2 - t_1},$$

$$C.y = \frac{t_1 \times M_b.y - t_2 \times M_a.y + t_1 t_2 (M_a.x - M_b.x)}{t_2 - t_1}.$$

Estimations of other parameters(Decomposing the parameter space)

$$N^2 = -\frac{(q_1 - K)(q_2 - K)}{(1 + q_1 K)(1 + q_2 K)},$$

with $K = \tan\rho$, $N = \frac{B}{A}$, $\alpha = q_1 q_2 - q_3 q_4$,

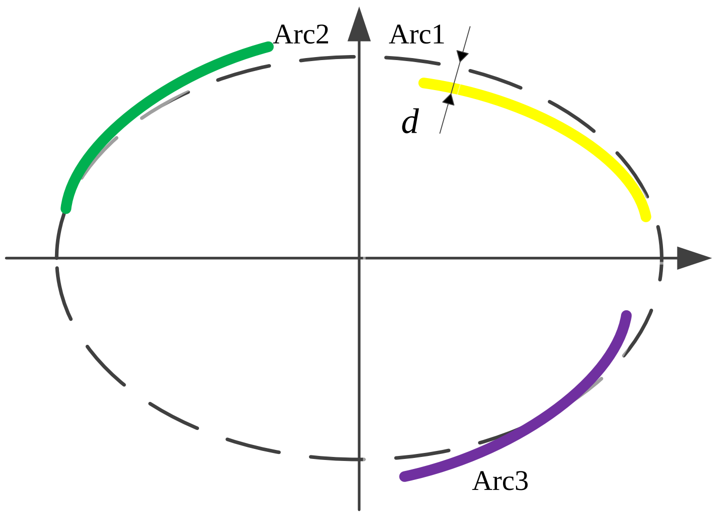
$\beta = q_2 q_4 (q_3 - q_1) + q_1 q_3 (q_4 - q_2) + (q_1 + q_2 - q_3 - q_4)$.Thus,

$$K = \pm\sqrt{1 - \frac{\beta}{\alpha}}.$$

Methodology

Validation

Validation by the ratio of circumference



Assuming that the coordinate of point is on an arc (x_i, y_i),we put this coordinate into the following equations:

$$X = \frac{[(x_i - x_c)\cos\rho + (y_i - y_c)\sin\rho]^2}{\alpha^2},$$

$$Y = \frac{[(y_i - y_c)\cos\rho - (x_i - x_c)\sin\rho]^2}{\beta^2},$$

$$d = |X + Y - 1| < Thre_d,$$

$$\psi(\tau_{123}) = \frac{N_{\mathcal{B}}}{N_1 + N_2 + N_3} > Thre_n$$

Experimental results

Benchmark

Public Datasets

1.Dataset of synthetic images

2.Dataset Prasad

3. Dataset #1

Compared Detectors

Bai *et al* (2009)
Liu *et. al* (2009)
Mai *et al* (2008)
Prasad *et al* (2012)
Fornaciari *et al* (2014)

Performance metrics

F-measure and the execution time *t*

The Precision and Recall values are computed as follows:

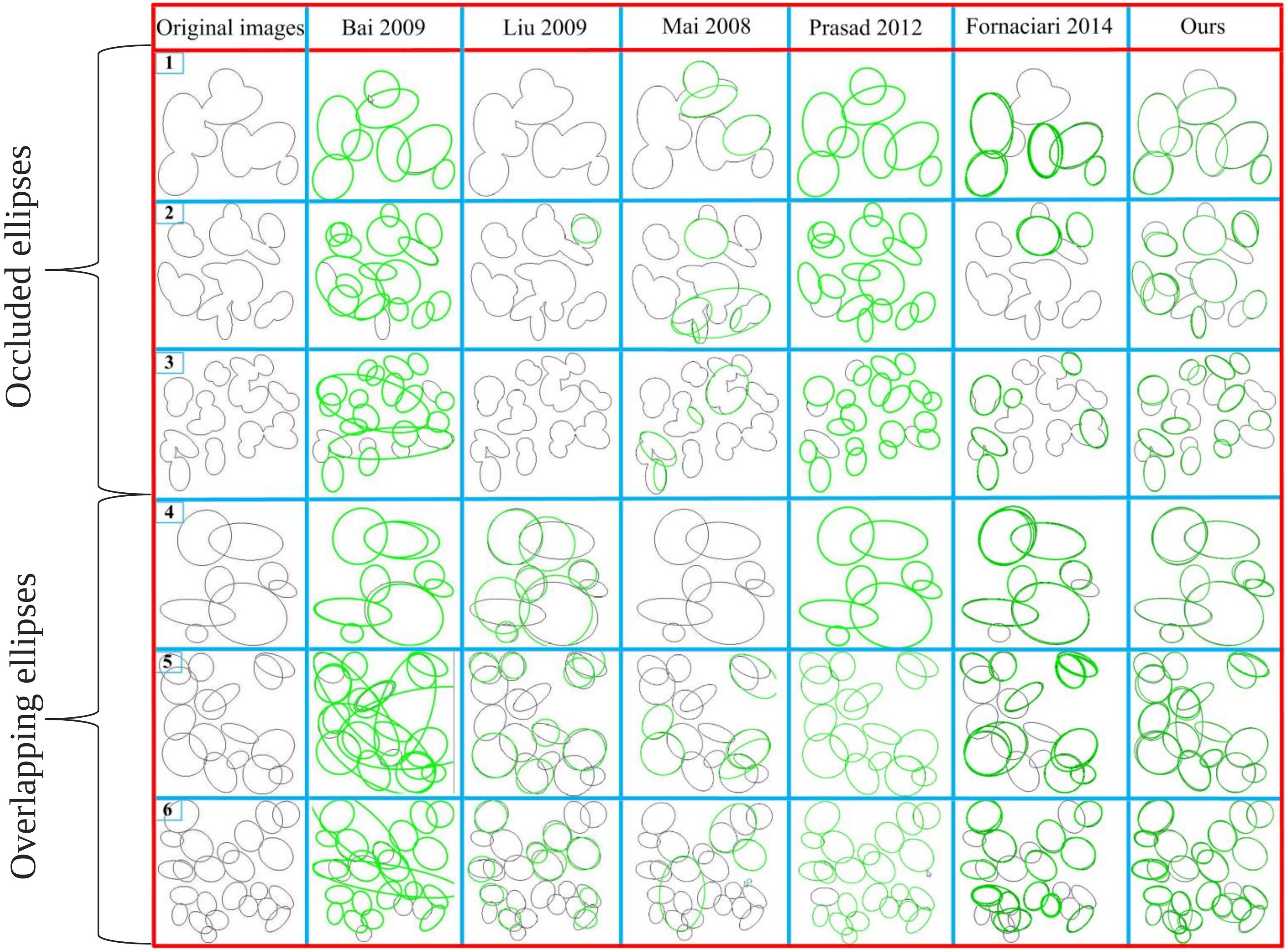
$$Precision = \frac{\Omega}{N}, \text{Recall} = \frac{\Omega}{M}.$$

F-measure is obtained as follows:

$$F\text{−measure} = \frac{2 \times Precision \times Recall}{Precision + Recall}.$$

Experimental results

Practical detection cases for Dataset of synthetic images



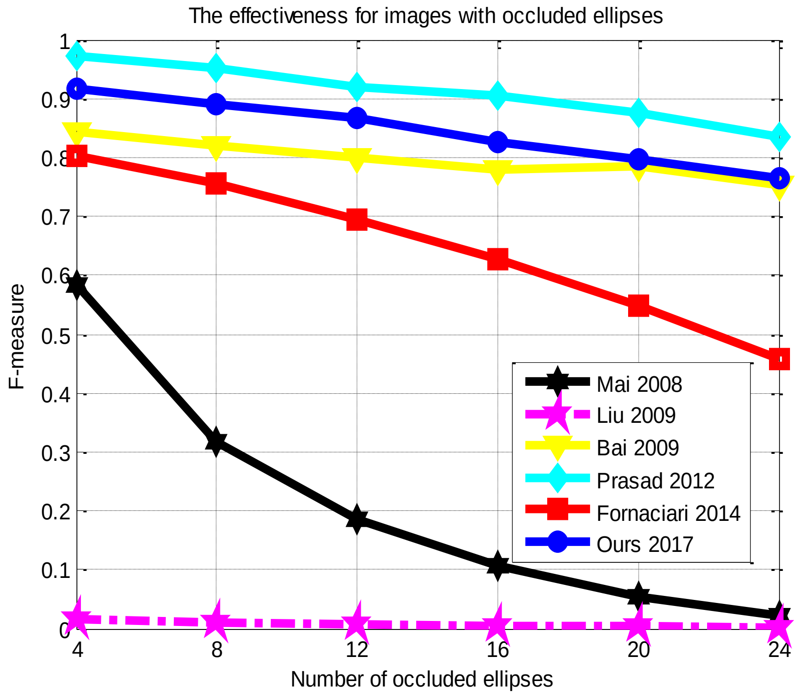
NANYANG TECHNOLOGICAL UNIVERSITY

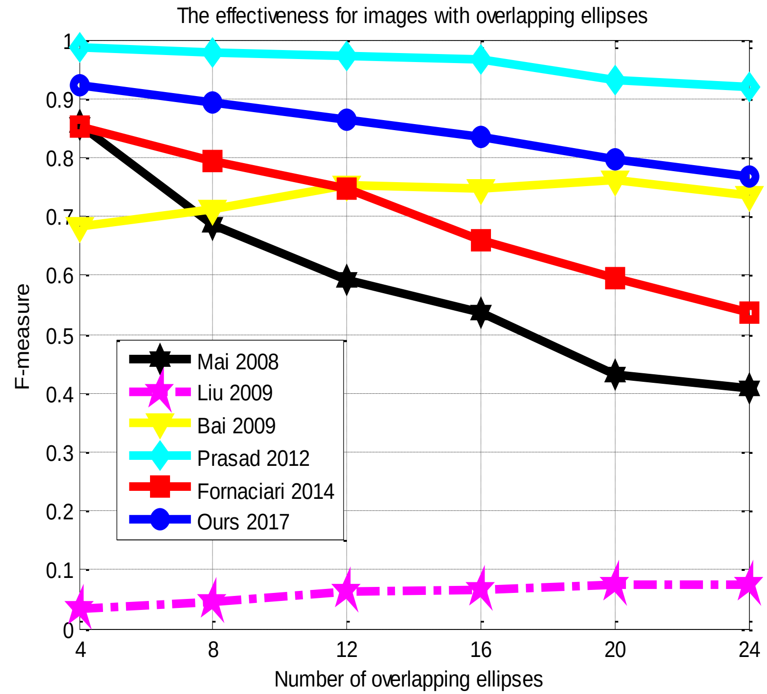
Experimental results

Practical detection cases for Dataset Prasad and Dataset #1

Experiment results

Detection results regarding F-measure for Dataset of synthetic images





Detection results for Dataset Prasad and Dataset #1

	Dataset Prasad		Dataset #1	
	F-measure(%)	Average time(ms)	F-measure(%)	Average time(ms)
Bai 2009	16.85	23.107	0.2604	1160
Liu 2009	8.08	20.06	0.1170	978.8
Mai 2008	18.31	28.53	0.2604	521.5
Prasad 2012	44.18	158.32	0.4512	1370
Fornaciari 2014	43.70	**5.56**	0.5716	**18.55**
Ours	**47.56**	18.17	**0.6031**	27.56

NANYANG TECHNOLOGICAL UNIVERSITY

Thank you a lot for your comments!