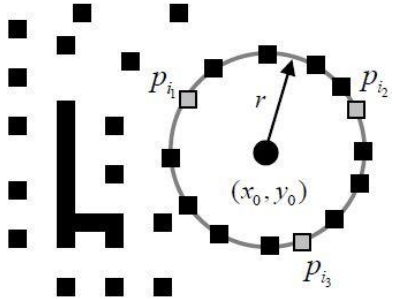
Mobile Device Camera Connector (Tabiscope)

Circle Detection with Learning Automata (LA)

Paper Seminar by Kyle Wong



600.446 Computer Integrated Surgery II
Project 7

Partners: Daniel Ahn, Deepak Lingam
Mentors: Dr. Amit Kochhar, Kevin Olds

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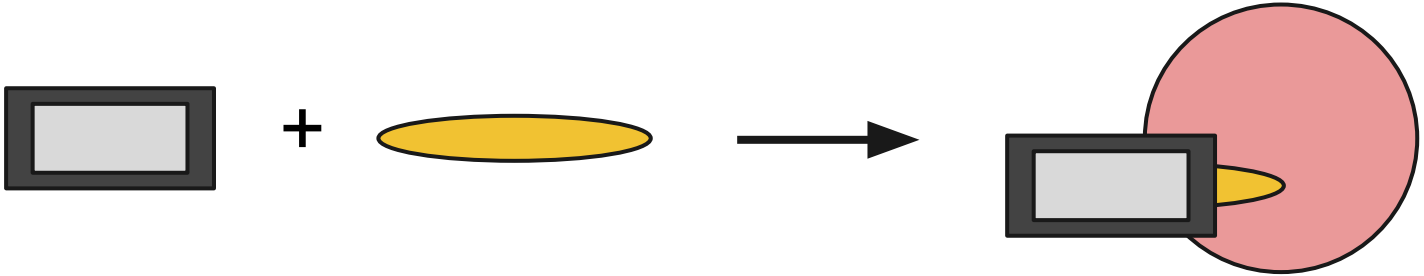
Project Overview

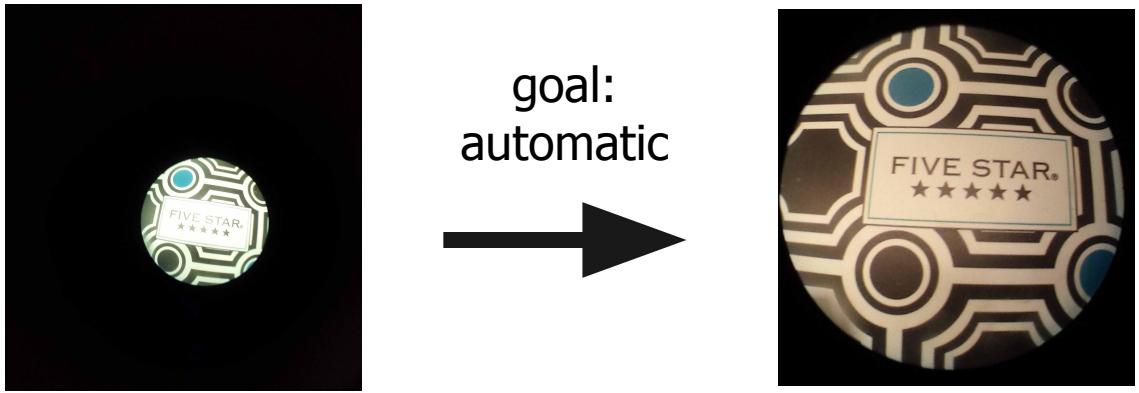
- Design a low cost endoscopic adapter



- Create a system for Android devices

Design Challenge

- Real-time image processing method for Circle Detection for auto-zoom, auto-focus, auto-brightness etc.



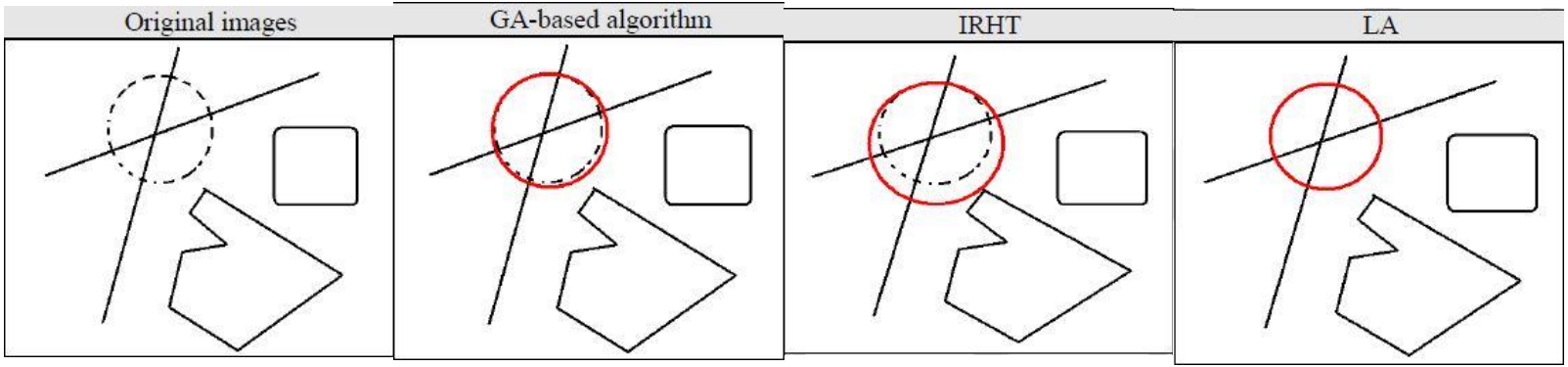
Paper Selection

Cuevas, E., Wario, F., Zaldivar, D., & Pérez-Cisneros, M. (2013). **Circle detection on images using learning automata**. In *Artificial Intelligence, Evolutionary Computing and Metaheuristics* (pp. 545-570). Springer Berlin Heidelberg

Cuevas '13. *Circle detection on images using learning automata.*

Summary of Problem and Results

- Circle detection quickly and accurately
- Create a set of synthetic and natural images for comparison
- Compare Learning Automata (LA) with Iterative Randomised Hough Transform (IRHT) and Genetic Algorithms (GA)



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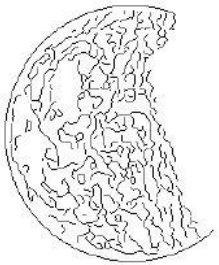
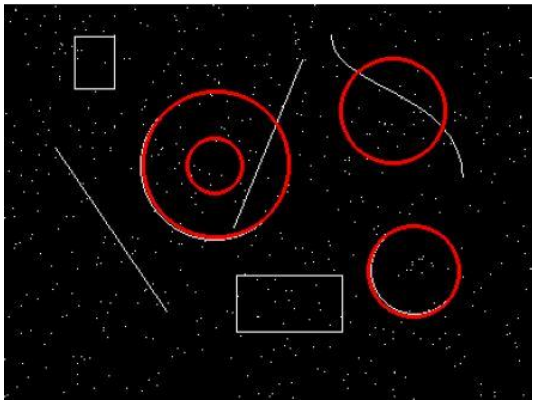
Significance

- LA algorithm works for occluded circles and multiple circles and is robust to noise and fast ⟶ widespread use





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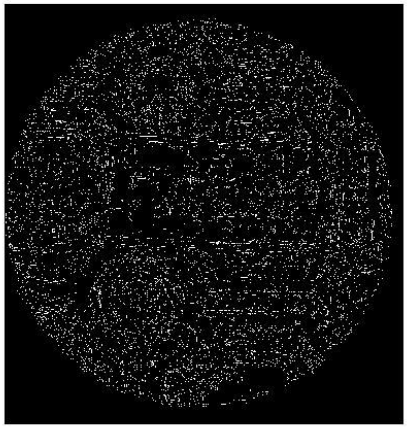
Background - LA

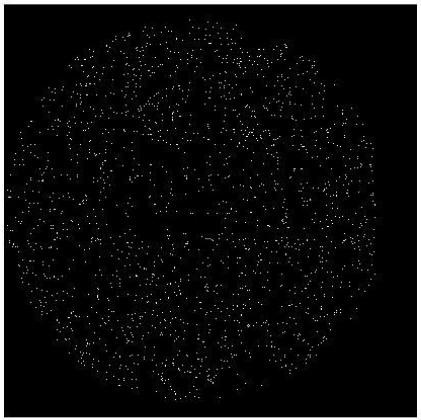
- **Learning** Automata (LA) optimize through a **learning** process
- Model actions applied to an environment with a probability density function (pdf)
- Pair actions with reinforcement signal to update the pdf to select the next action
- Iterate until optimal action is found (threshold reached, or number of iterations is done)

Background - Preprocess

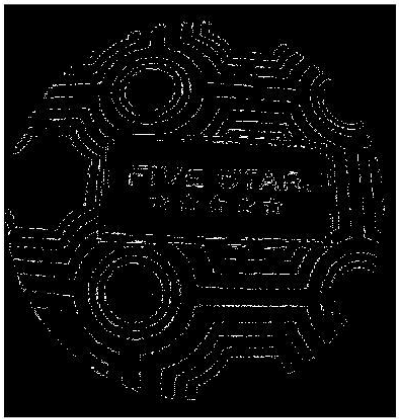
- pre-process with Canny Algorithm to get single-pixel edge map; take only a fraction (about 5%) randomly



Matlab - Canny Method



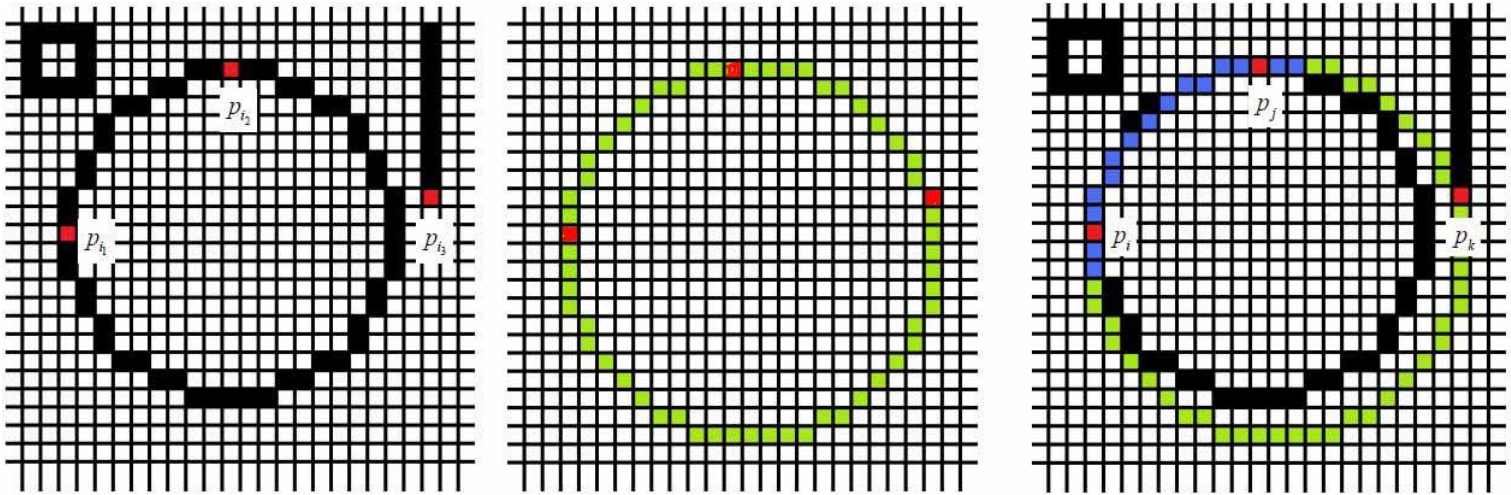
Random Sample



Matlab - Sobel Method

Background - Sample

- sample combinations of 3 points and check



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Background 3 Circle-find

- Circle calculation

$$x_0 = \frac{\det(\boldsymbol{A})}{4((x_{i_2} - x_{i_1})(y_{i_3} - y_{i_1}) - (x_{i_3} - x_i)(y_{i_2} - y_{i_1}))}$$

$$y_0 = \frac{\det(\boldsymbol{B})}{4((x_{i_2} - x_i)(y_{i_3} - y_{i_1}) - (x_{i_3} - x_{i_1})(y_{i_2} - y_{i_1}))}$$

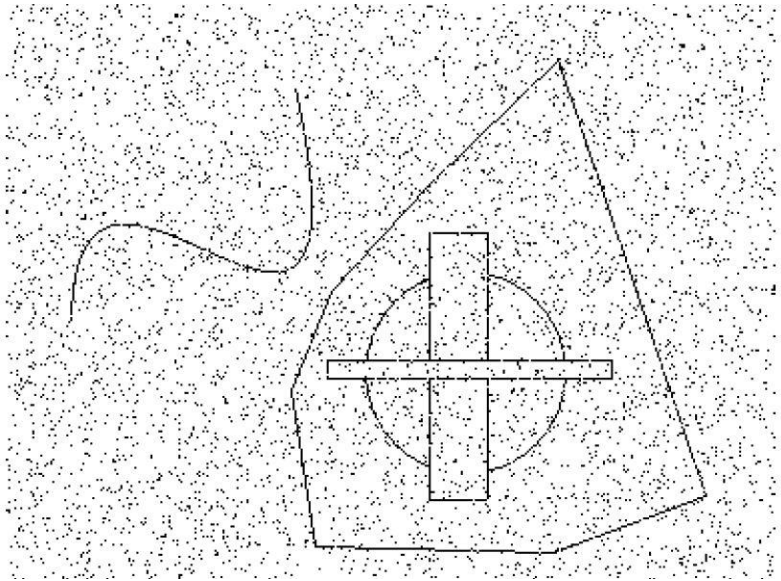
$$\boldsymbol{A} = \begin{bmatrix} x_{i_2}^2 + y_{i_2}^2 - (x_{i_1}^2 + y_{i_1}^2) & 2(y_{i_1} - y_{i_1}) \\ x_{i_3}^2 + y_{i_3}^2 - (x_{i_1}^2 + y_{i_1}^2) & 2(y_{i_3} - y_{i_1}) \end{bmatrix}$$

$$\boldsymbol{B} = \begin{bmatrix} 2(x_{i_2} - x_{i_1}) & x_{i_2}^2 + y_{i_2}^2 - (x_{i_1}^2 + y_{i_1}^2) \\ 2(x_{i_3} - x_{i_1}) & x_{i_3}^2 + y_{i_3}^2 - (x_{i_1}^2 + y_{i_1}^2) \end{bmatrix}$$

$$r = \sqrt{(x_0 - x_d)^2 + (y_0 - y_d)^2}$$

Methods

- Synthetic images with noise



- Real life images

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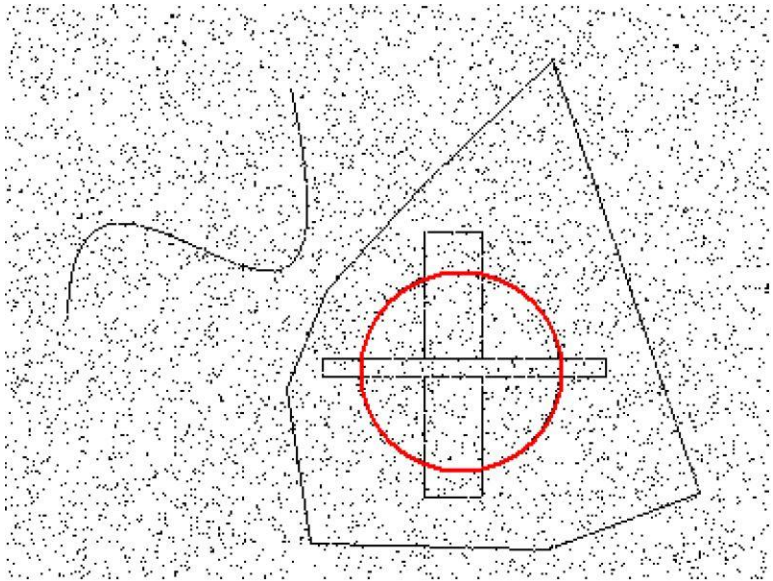
Methods - LA

- Synthetic images with noise



- Real life images

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Results

Image	Averaged execution time ± standard deviation, s			Averaged E_s ± standard deviation		
	GA	IRHT	LA	GA	IRHT	LA
Synthetic images						
(a)	2.23 ± (0.41)	1.71 ± (0.51)	**0.21 ± (0.22)**	0.41 ± (0.044)	0.33 ± (0.052)	**0.22 ± (0.033)**
(b)	3.15 ± (0.39)	2.80 ± (0.65)	**0.36 ± (0.24)**	0.51 ± (0.038)	0.37 ± (0.032)	**0.26 ± (0.041)**
(c)	3.02 ± (0.63)	4.11 ± (0.71)	**0.64 ± (0.19)**	0.71 ± (0.036)	0.77 ± (0.044)	**0.42 ± (0.011)**
Natural images						
(a)	2.02 ± (0.32)	3.11 ± (0.41)	**0.31 ± (0.12)**	0.45 ± (0.051)	0.41 ± (0.029)	**0.25 ± (0.037)**
(b)	2.11 ± (0.31)	3.04 ± (0.29)	**0.57 ± (0.13)**	0.87 ± (0.071)	0.71 ± (0.051)	**0.54 ± (0.071)**
(c)	2.50 ± (0.39)	2.80 ± (0.17)	**0.51 ± (0.11)**	0.67 ± (0.081)	0.61 ± (0.048)	**0.31 ± (0.015)**

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Results - LA Best

Image	Averaged execution time ± standard deviation, s			Averaged E_s ± standard deviation		
	GA	IRHT	LA	GA	IRHT	LA
Synthetic images						
(a)	2.23 ± (0.41)	1.71 ± (0.51)	**0.21 ± (0.22)**	0.41 ± (0.044)	0.33 ± (0.052)	**0.22 ± (0.033)**
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Assessment

Positive

- Thorough explanation and dataset results

Negative

- Self-constructed accuracy (arbitrary and biased?)

$$E_s = \eta(|x_{true} - x_D| + |y_{true} - y_D|) + \mu|r_{true} - r_D|$$

$E_s = \text{Error score}$

$\eta = \text{weight for accuracy of the center (chosen } 0.05)$

$\mu = \text{weight for accuracy of the radius (chosen } 0.1)$

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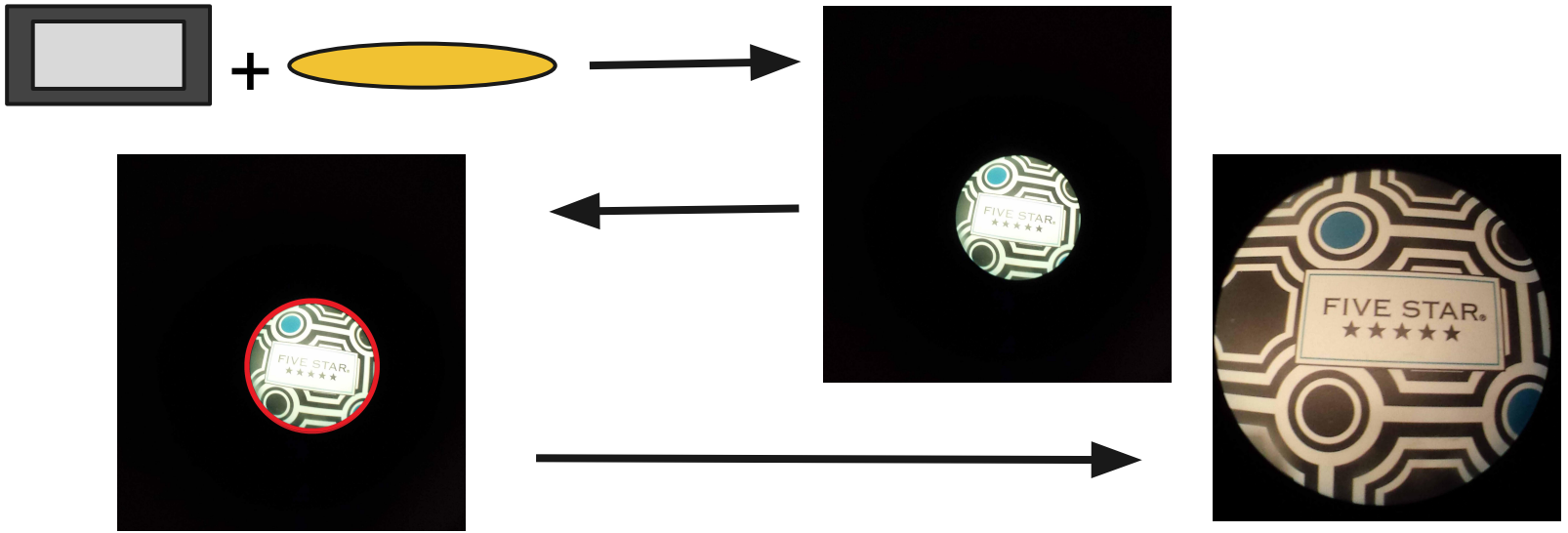
Future Work

- Compare to other methods like supposedly fast Randomized Circle Detection (accuracy and speed tradeoff)
- Compare to basic Circular Hough Transform (for a baseline)
- Implement in real-time to show capabilities (using real-time Canny edge detector)

Relevance to our Project

- Rapid and accurate circle detection in Endoscopic image
- 

Conclusions

- Circle Detection and shape recognition are still being researched
- Speed, accuracy, memory use, and robustness are vital considerations
- Having a standard of measuring these is essential for benchmarking
    - Learning Automata for Circle Detection may be of use for our Endoscope application

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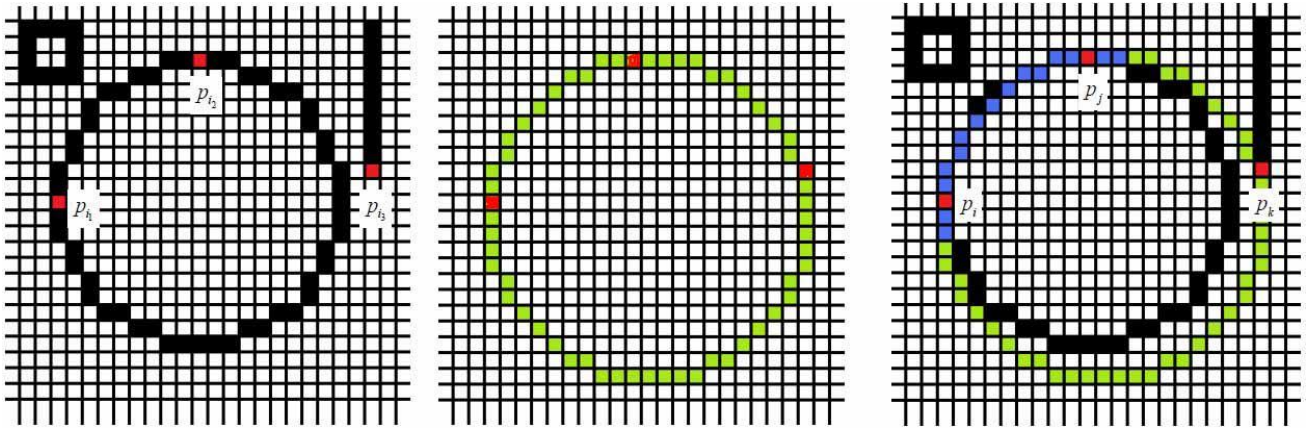
Circle Detection with Learning Automata (LA)

- Questions and Feedback?



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