TOSHIBA

Leading Innovation >>>

A New Lithography Hotspot Detection Framework Based on AdaBoost Classifier and Simplified Feature Extraction

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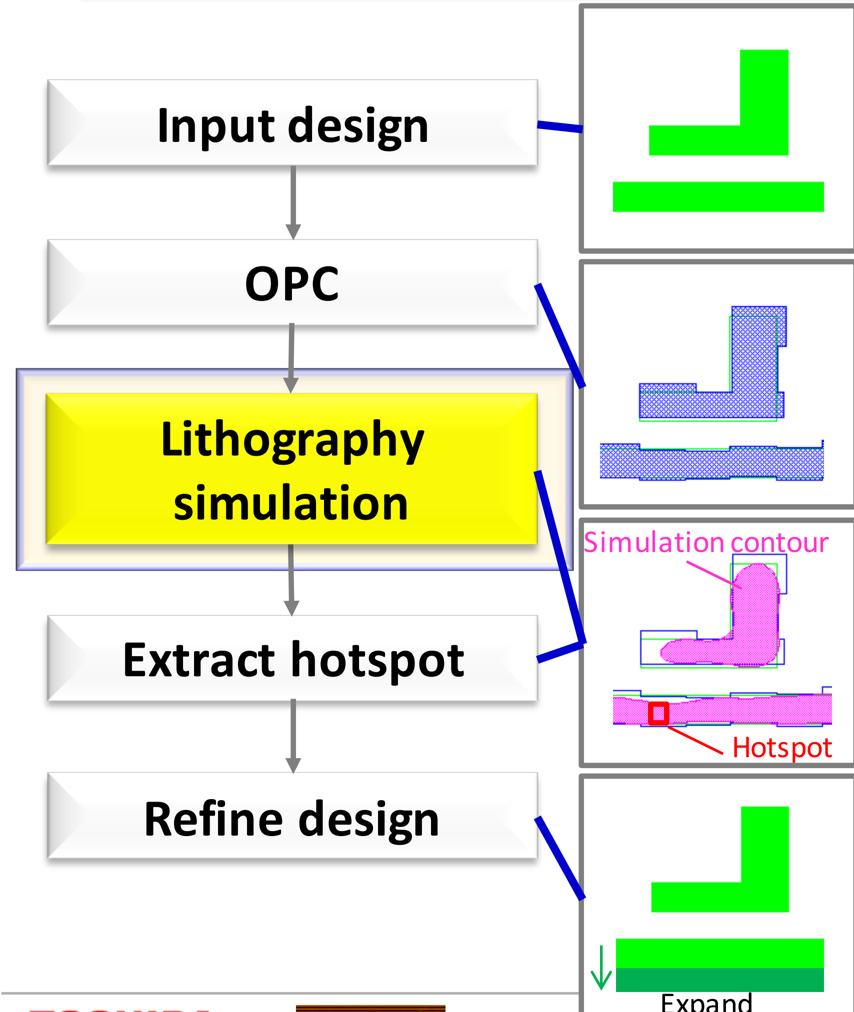
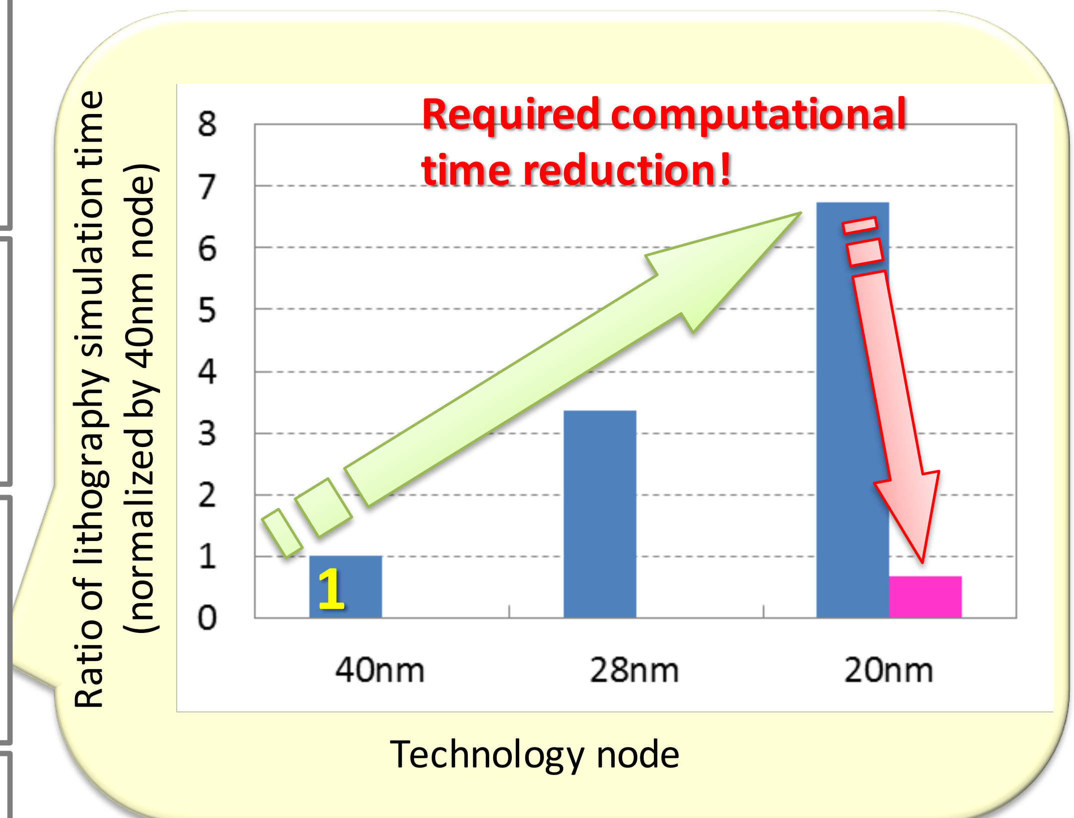
Outline

- Background
- Simplified Feature Extraction
- AdaBoost Classifier
- Experimental results
- Conclusion

Hotspot detection

- **Issue: Lithography simulation is time consuming**
- **Goal: High accurate hotspot detection in short runtime**

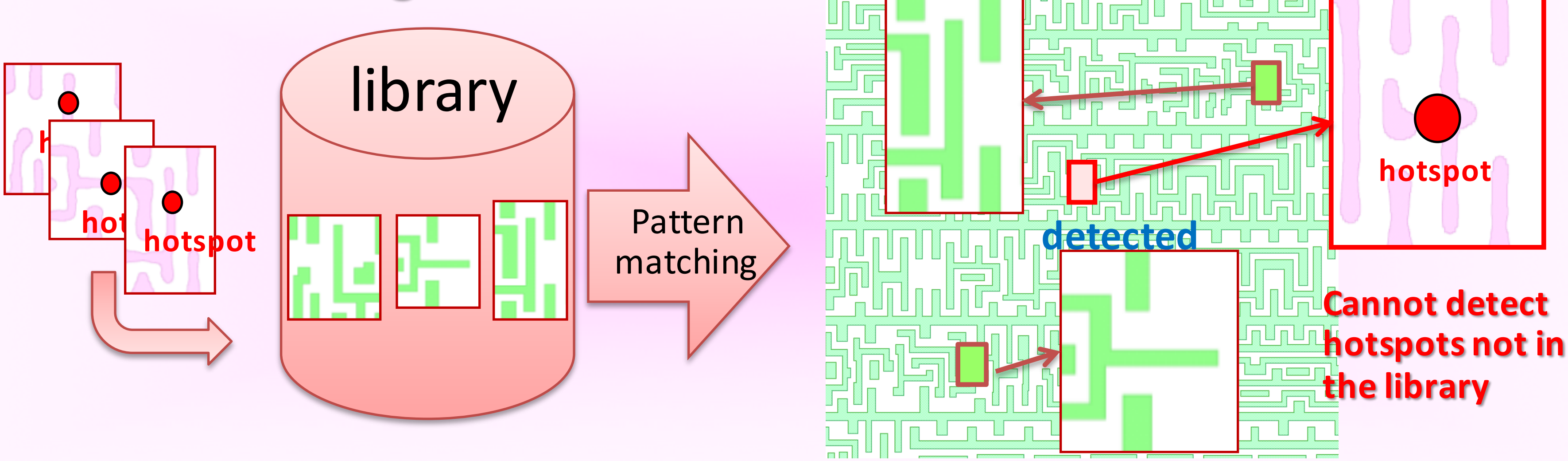




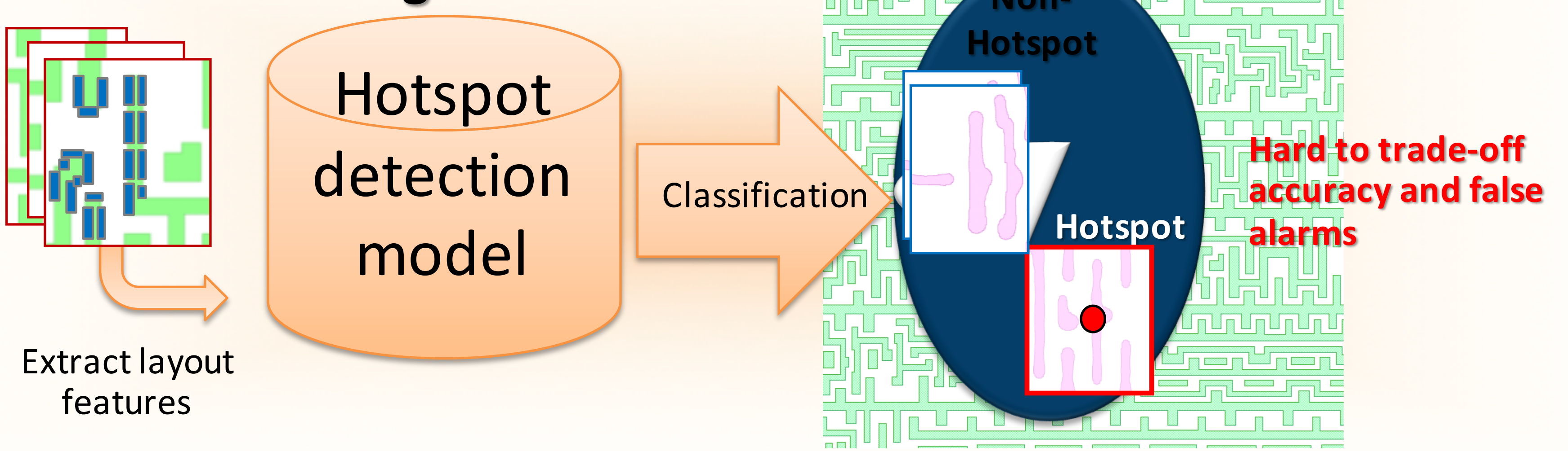
Simulation-based hotspot detection is the most widely used technique

Two major simulation-less approaches

Pattern Matching



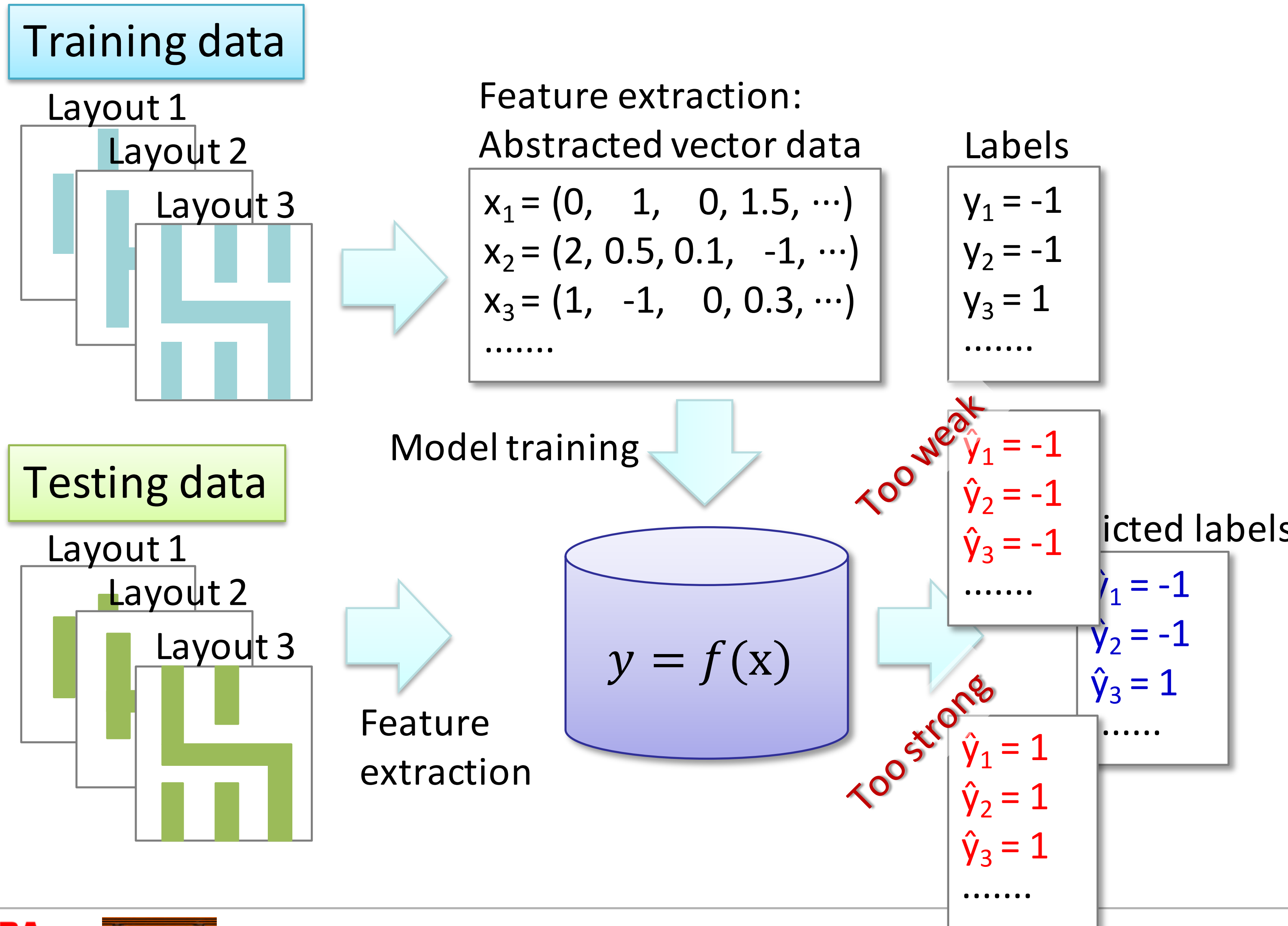
Machine Learning



Issues of conventional methods

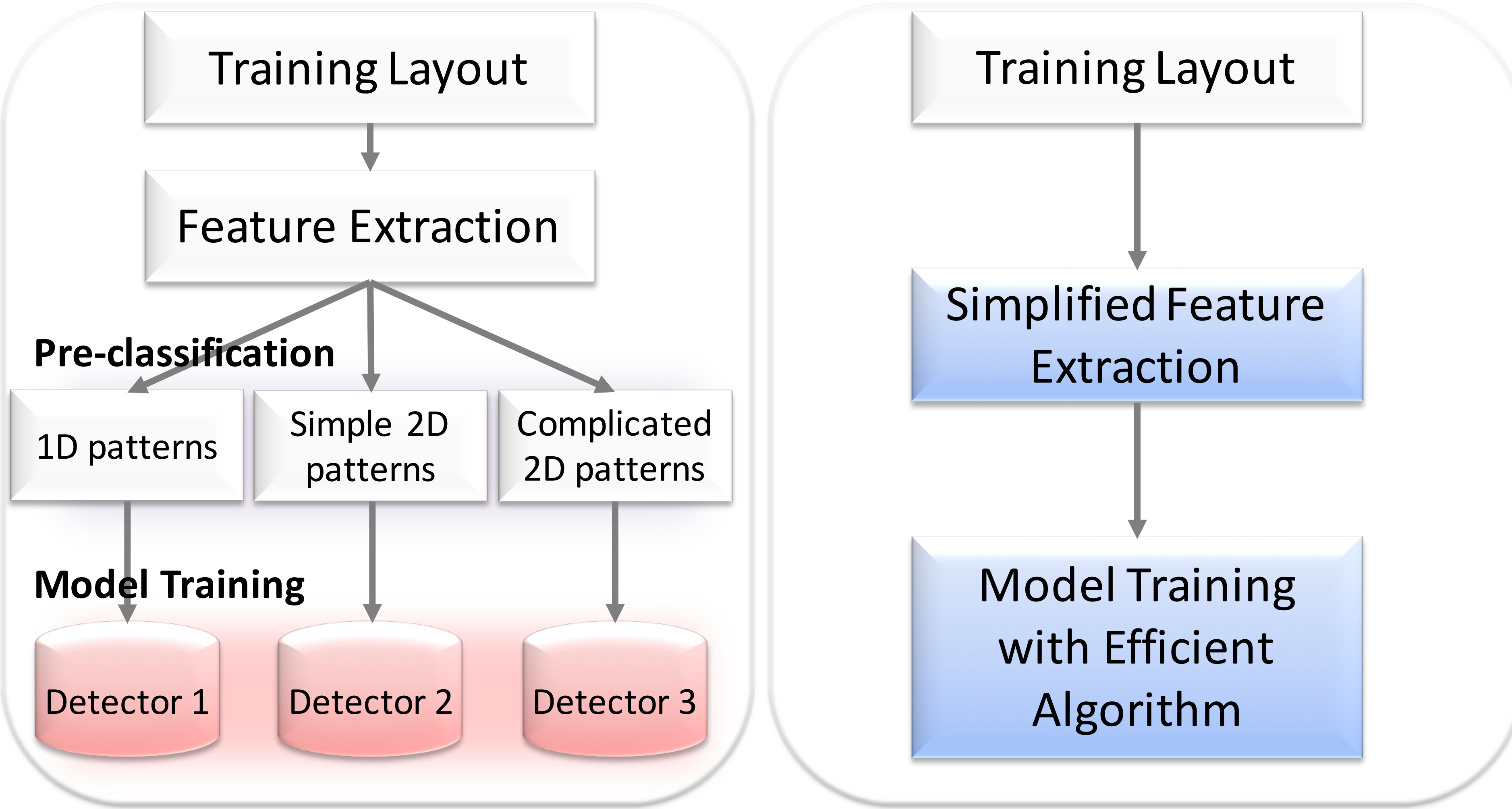
- **Lithography Simulation-based**
  - Time consuming
- **Pattern Matching-based**
  - Cannot detect unknown hotspot
- **Machine Learning-based**
  - Trade off relation between accuracy and false-alarm

Machine learning based hotspot detection



New hotspot detection framework

State-of-the-art approach | **Our framework**



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What is a "Simplified Feature"

- **Optimized layout feature to make model training easier**

1
- Feature extraction

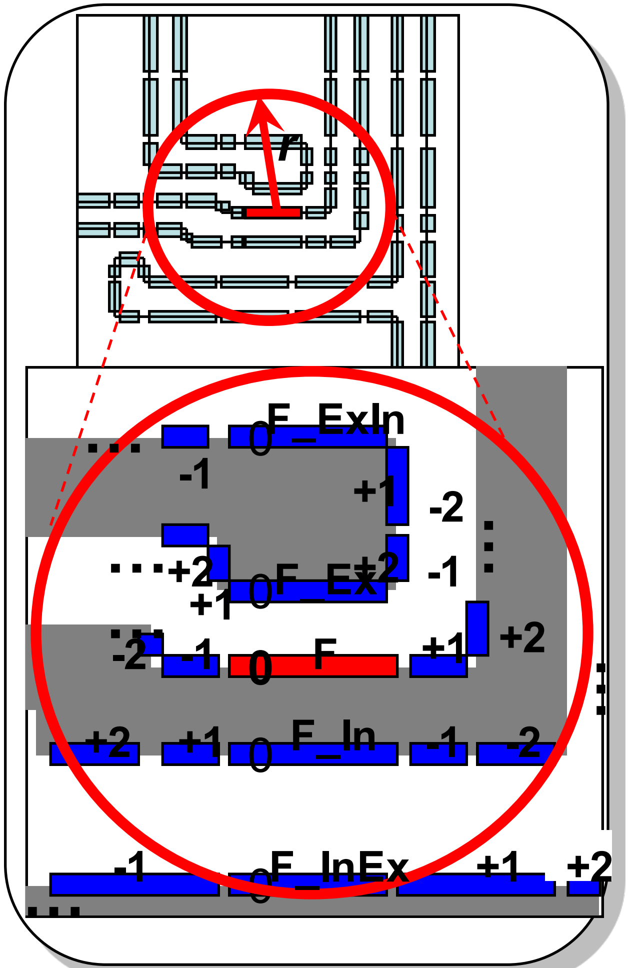
2
- Feature space analysis

3
- Optimal feature selection

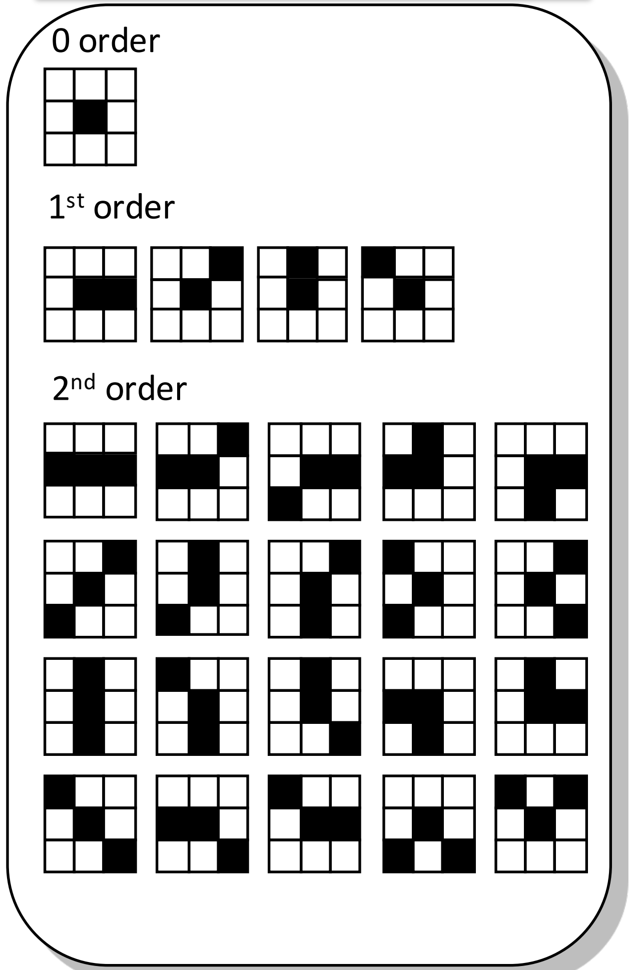
Optimized layout feature and parameters

Layout features

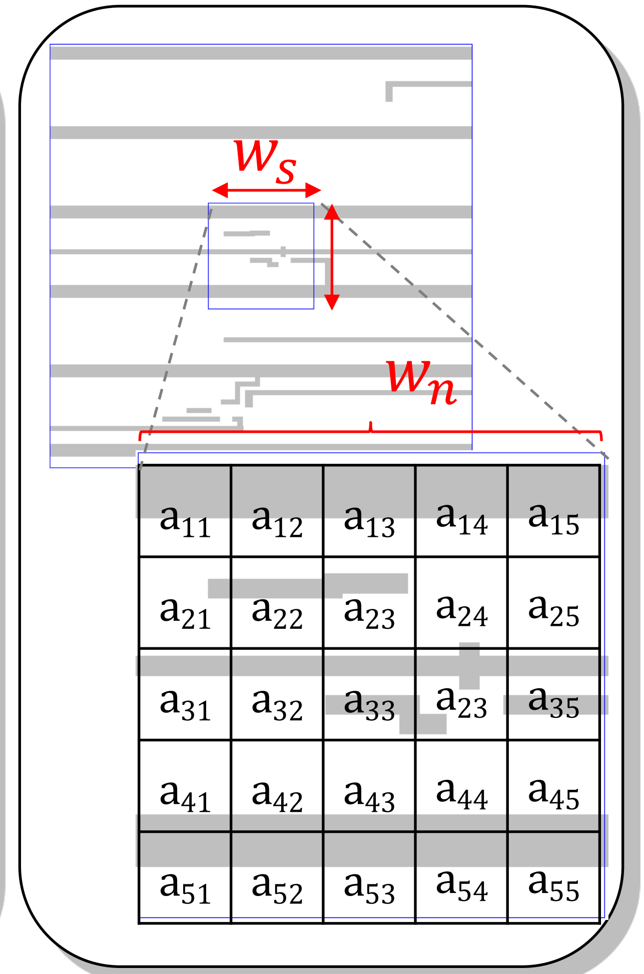
Fragmentation-based



Higher order local auto-correlation

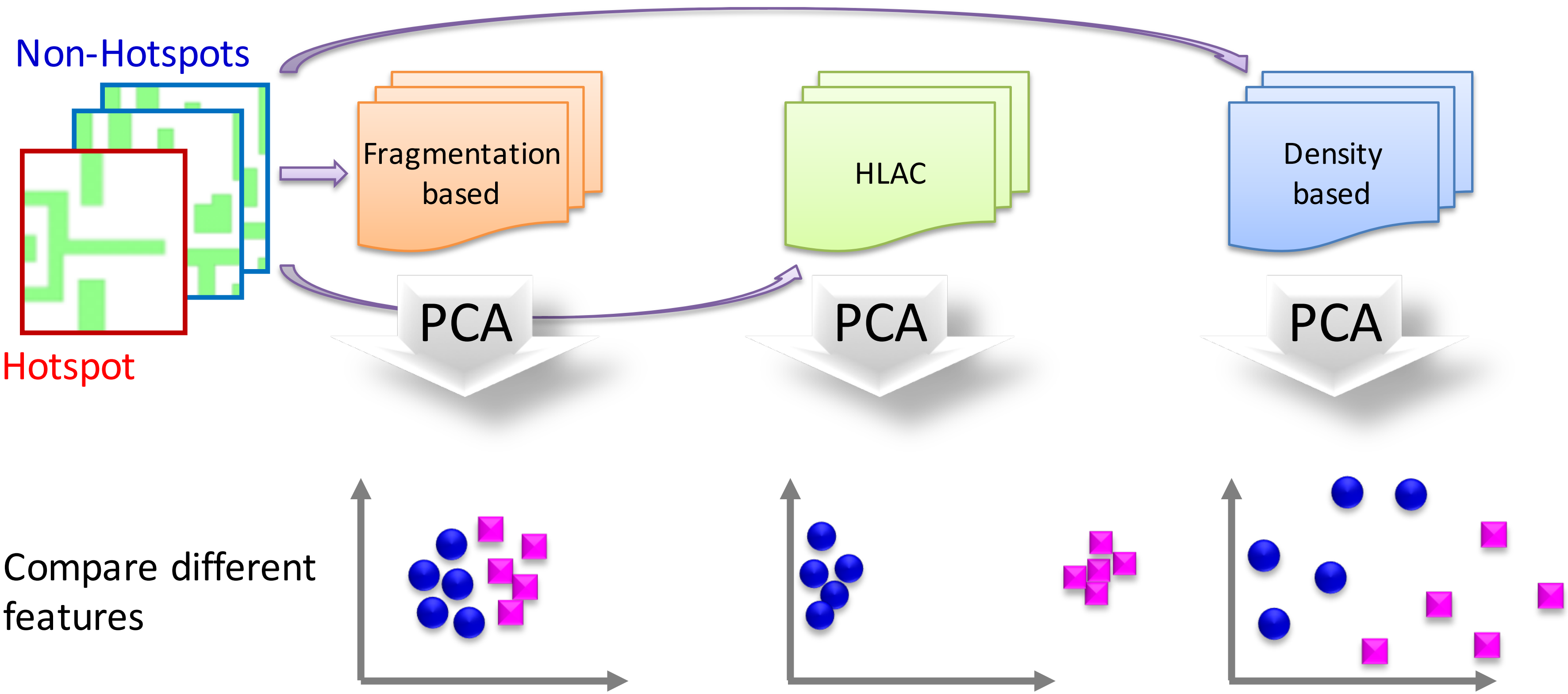


Density-based



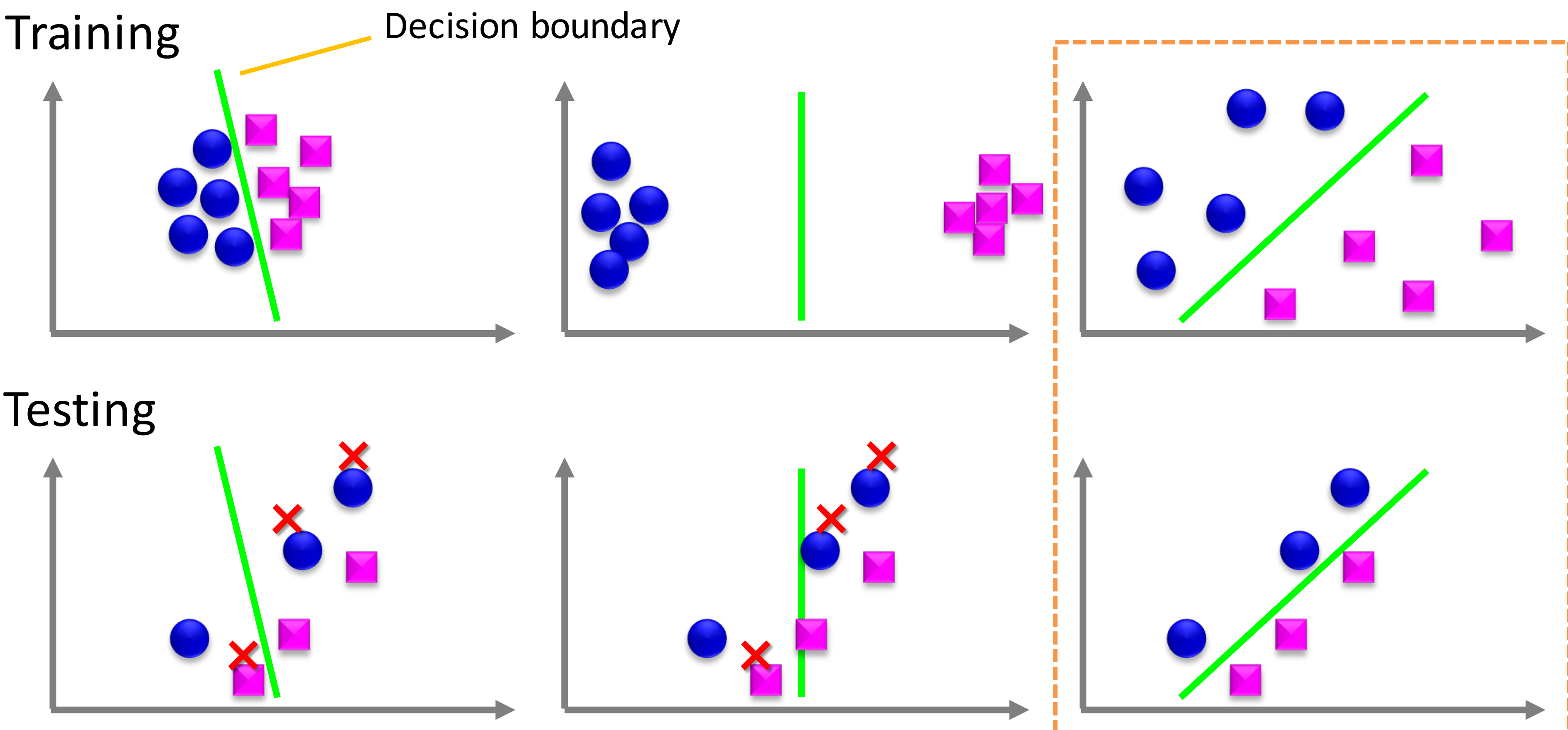
Feature space analysis

- **Principal Component Analysis (PCA)**
  - Dimensionality reduction based on orthogonal transformation
- **Mahalanobis Distance**
  - Normalized Euclidean distance



Dimensionally reduced feature space

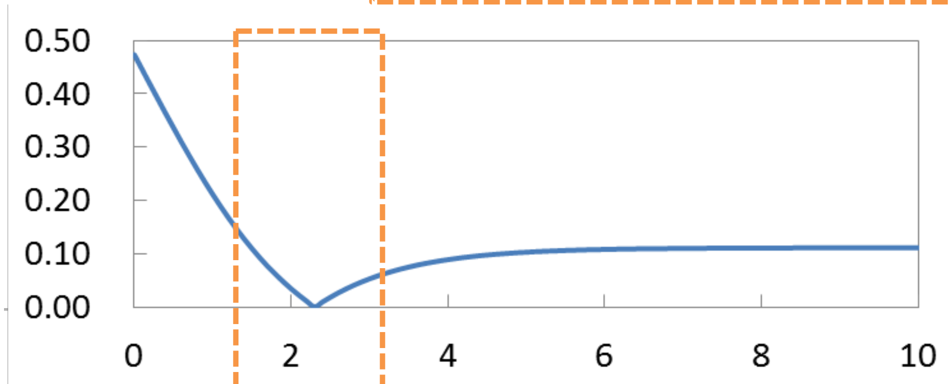
Feature space analysis for generalization capability



Feature space index

$$H = \left| 1 - \frac{1}{\alpha + \exp(D_m)} \right|$$

Mahalanobis distance between Hotspots and Non-Hotspots

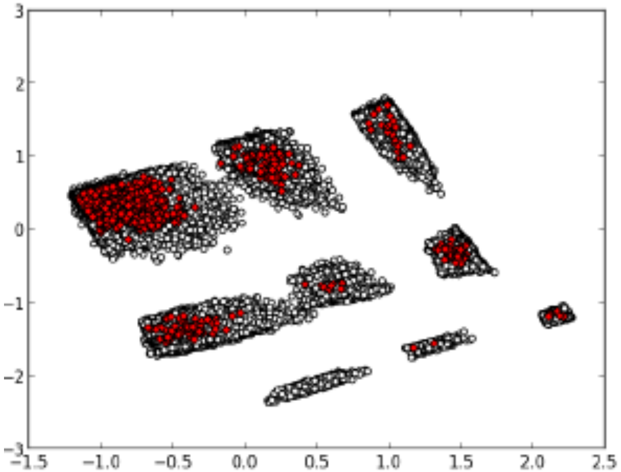


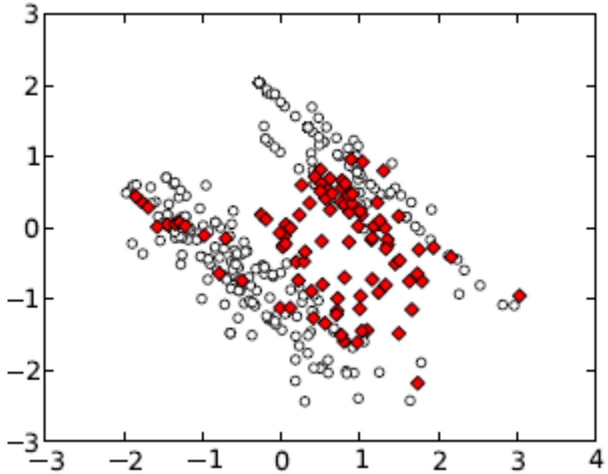
Comparison of different features

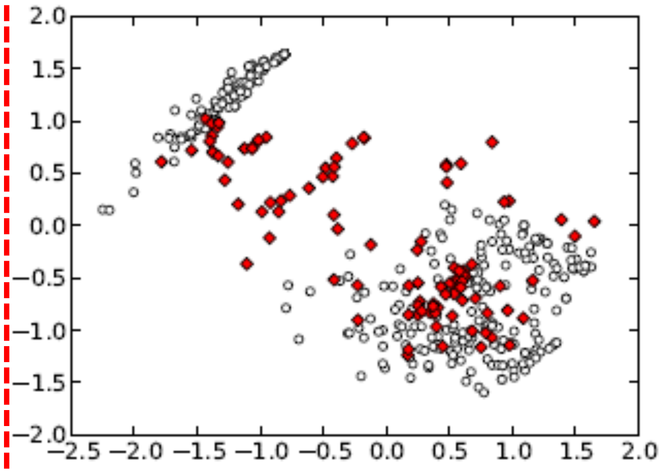
Fragmentation-based

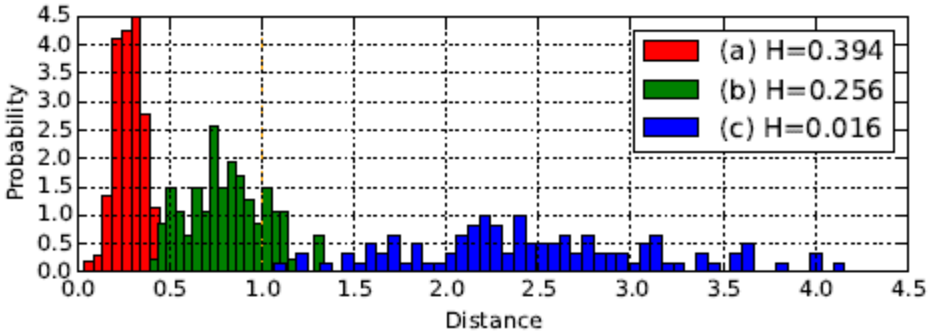
Higher order local auto-correlation

Density-based









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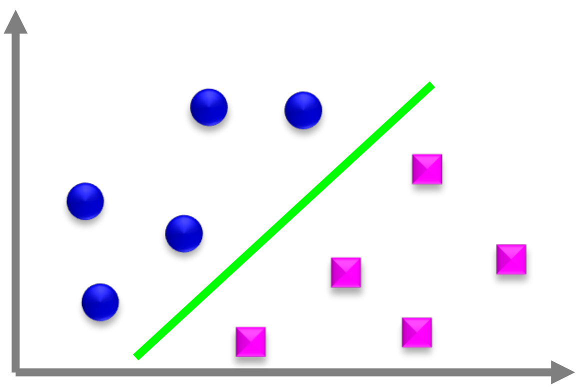
Machine learning algorithms

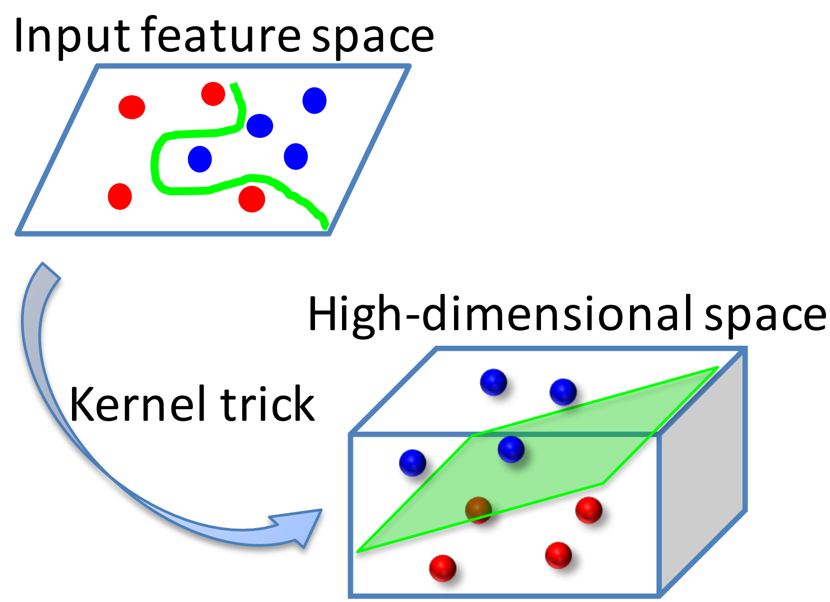
LR
(Logistic Regression)



$$y(\mathbf{x}) = \sigma\left(\mathbf{w}^{\mathrm{T}}\mathbf{x}\right)$$

$$\sigma(a) = \frac{1}{1 + \exp(-a)}$$

SVM
(Support Vector Machine)



How to learn hotpot features

Why AdaBoost algorithm?

Hotspot detection is extremely complicated multiclass-classification problem

➢ Hotspot has many defect mode

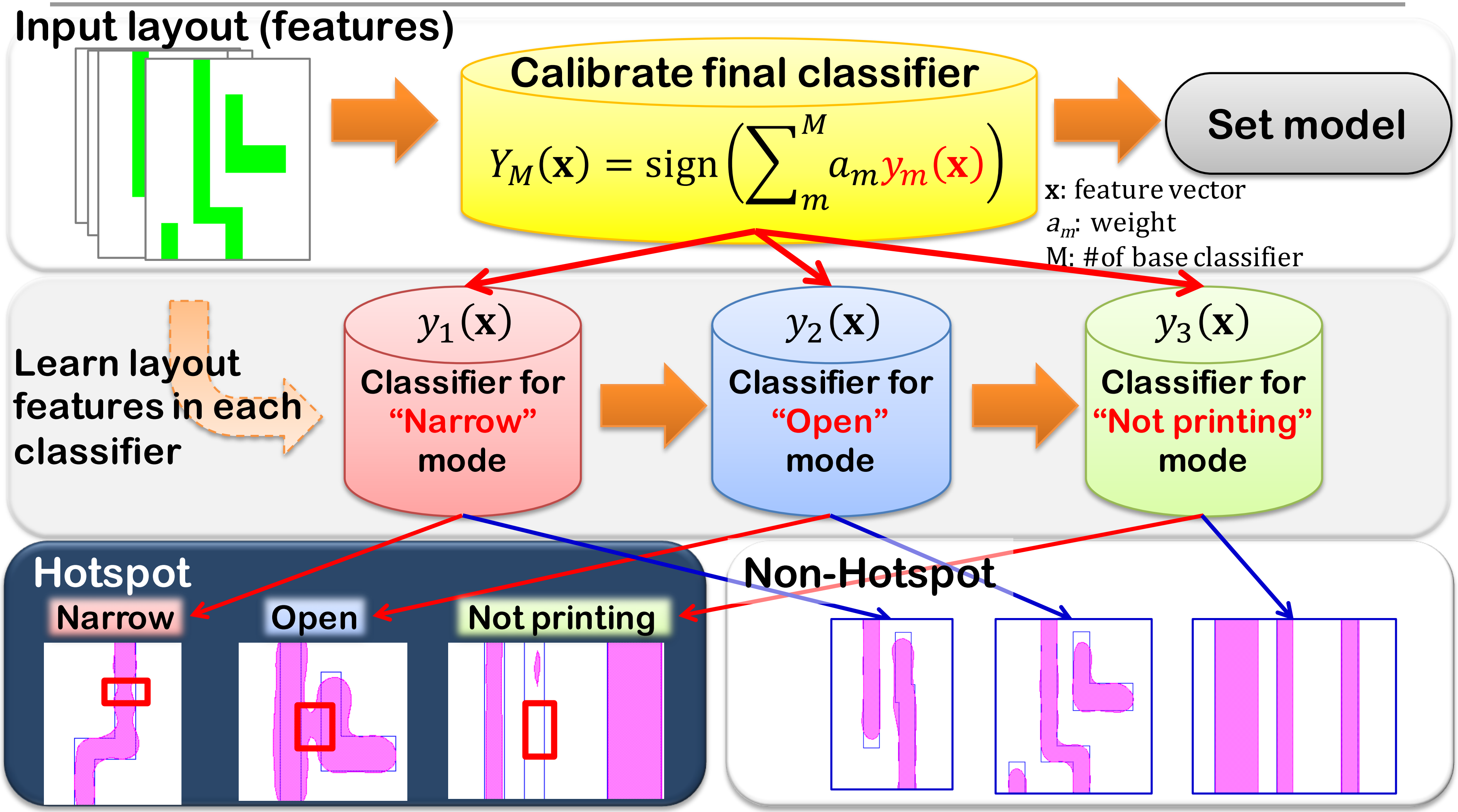
Conventional method is hard to generalize all variations of hotspot features

➢ Accuracy limitation because of too many factors of hotspot

AdaBoost can simultaneously learn many factors of hotspot

➢ Utilize boosting algorithm in conjunction with several classifiers

AdaBoost Classifier



Generalize final classifier in conjunction with base classifiers corresponding to many defect modes

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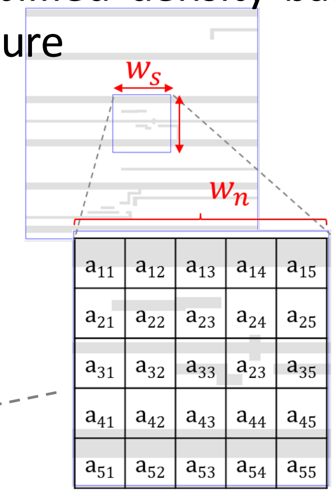
Detection model training

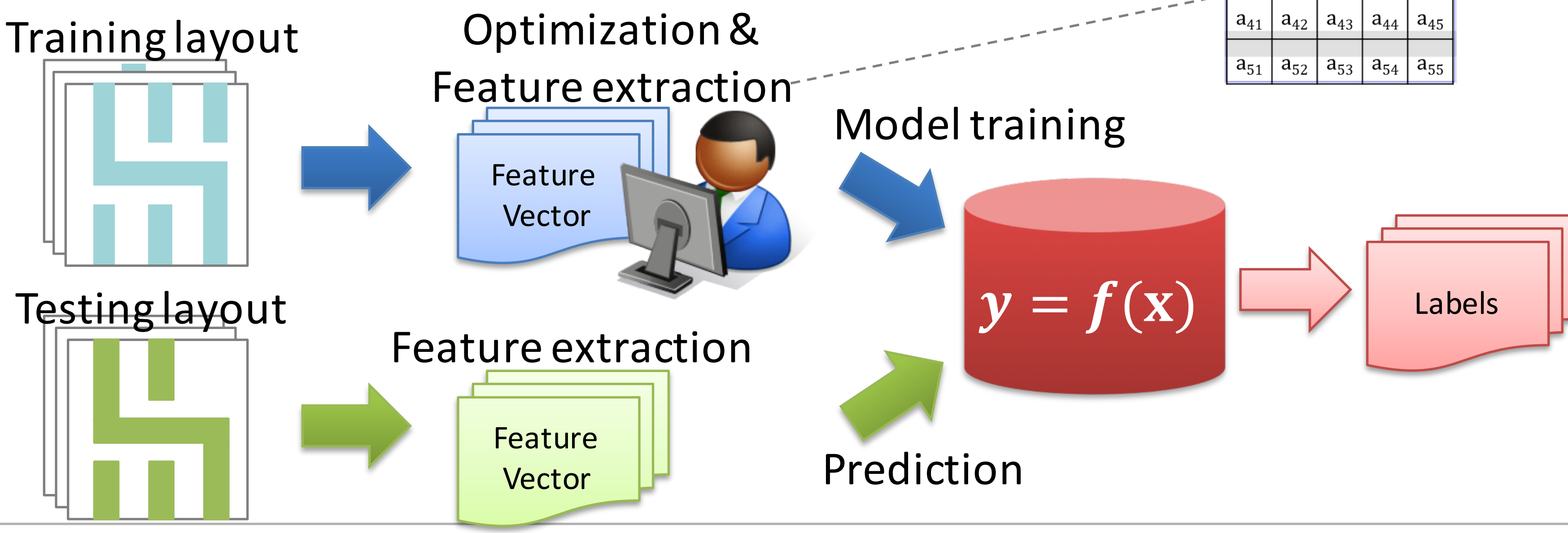
- ICCAD 2012 Benchmark Problem3*

*http://cad_contest.cs.nctu.edu.tw/CAD-contest-at-ICCAD2012/problems/p3/p3.html

Data	Size(KB) Train/Predict	#of HS Train/Predict	#of NHS Train/Predict
Benchmark1	918 / 1112	99 / 226	340 / 319
Benchmark2	31655 / 28043	174 / 498	5285 / 4145
Benchmark3	29933 / 33333	909 / 1808	4643 / 3541
Benchmark4	12320 / 10072	95 / 177	4451/ 3386
Benchmark5	5726 / 4893	26 / 41	2716 / 2111

Simplified density-based feature





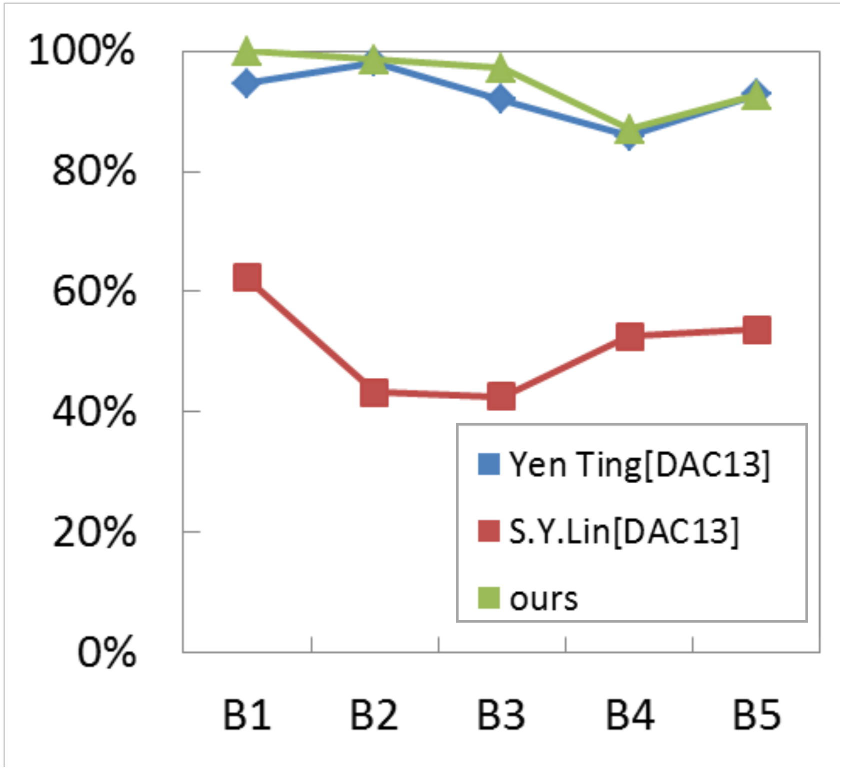
Comparison experiments

- Comparison with related detection methods:
  - [1] Topological classification and critical feature extraction , Yen Ting et. al., (DAC'13)
  - [2] Fuzzy matching model, S. Y. Lin et. al., (DAC'13)
- Comparison of different algorithms:
  - Logistic Regression and Support Vector Machine

Comparison with state-of-the-art methods

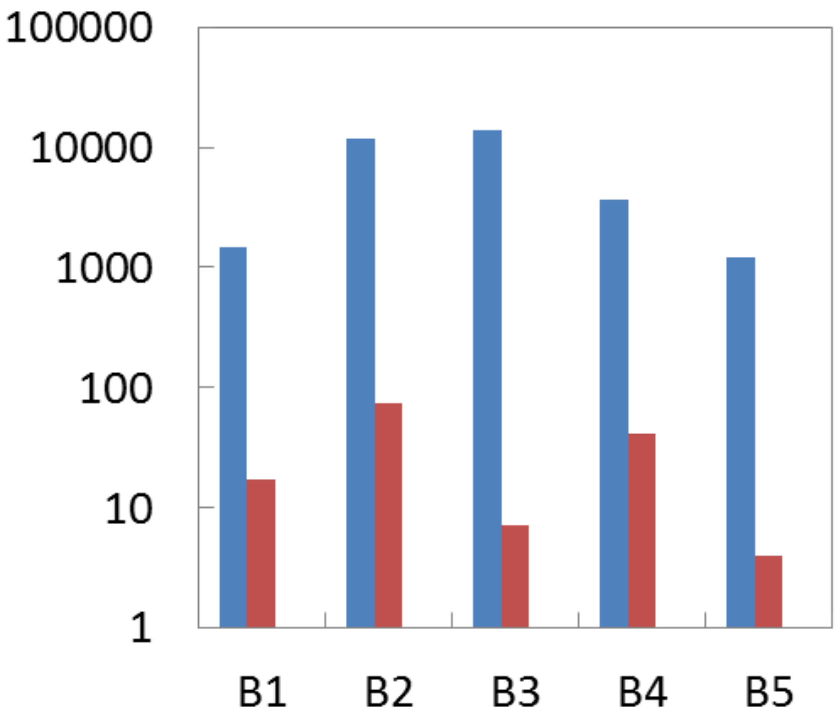
Detection Accuracy

(#correctly detected hotspots/#total hotspots)



False Alarm

(#of falsely detected patterns as hotspots)

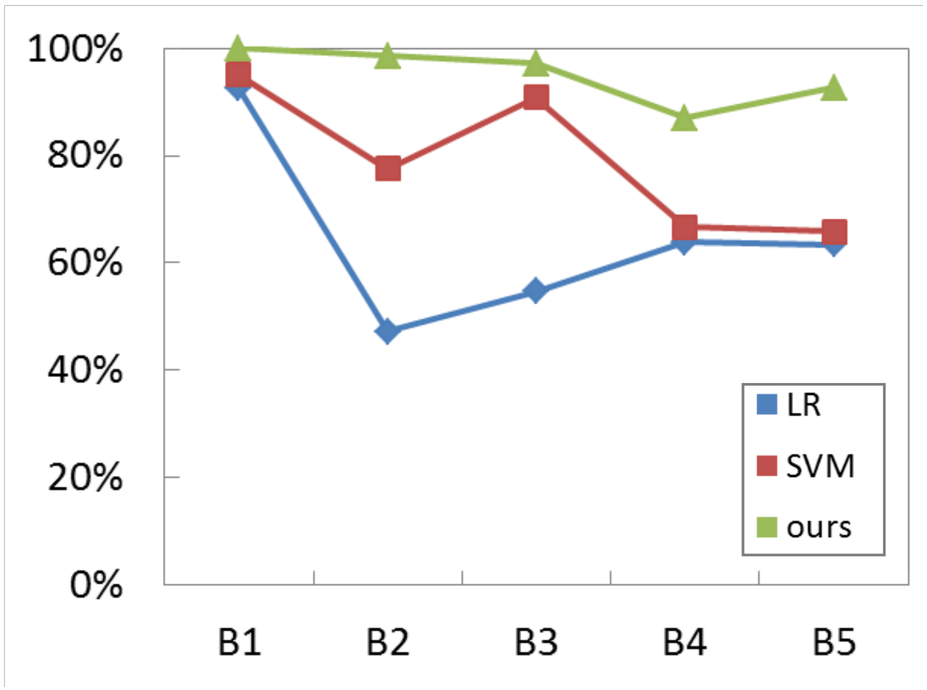


Average 95% accuracy with almost 0 false alarm

Comparison of different algorithms

Detection Accuracy

(#correctly detected hotspots/#total hotspots)



False Alarm

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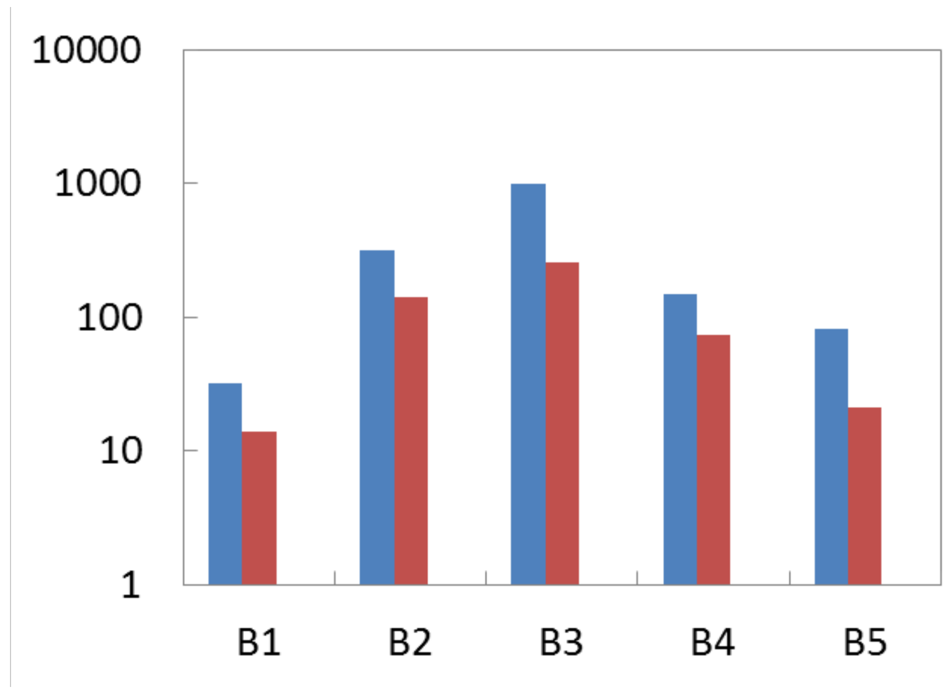

Average 95% accuracy with almost 0 false alarm

Conclusion

- Toshiba and UTDA developed a new hotspot detection framework.
- Our method utilizes AdaBoost classifier and simplified feature extraction method.
- Experimental results show that our method can achieve over 95% accuracy with almost 0 false-alarm.