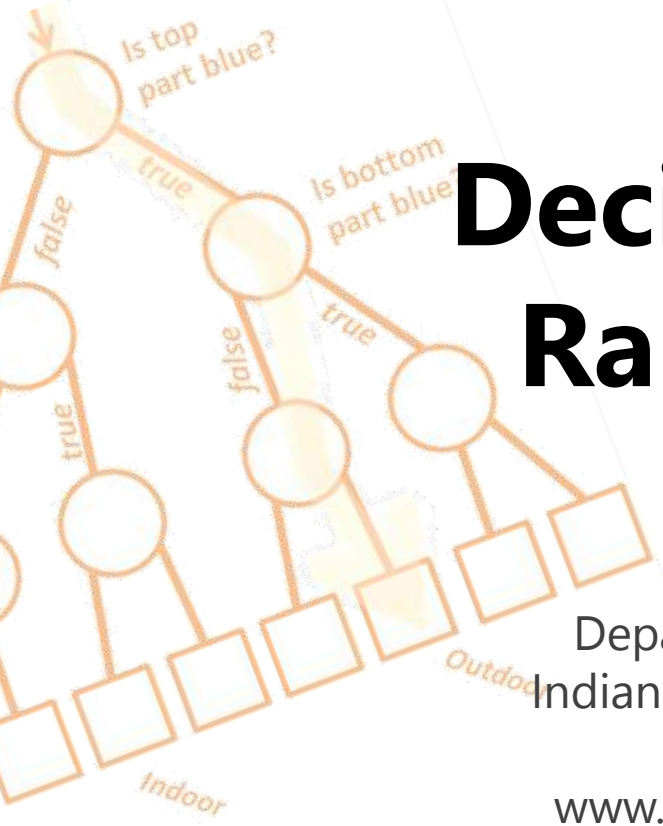
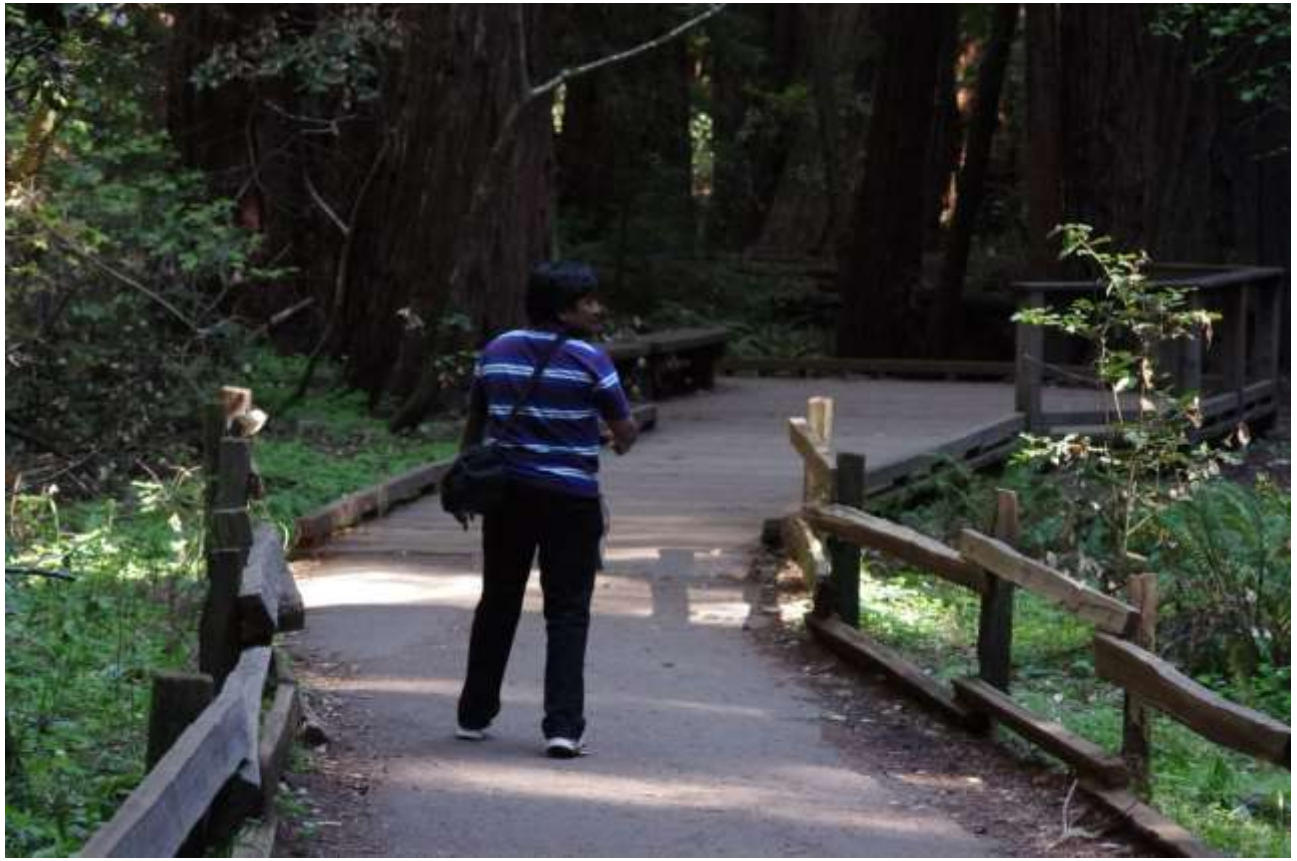


Decision Trees and Random Forests

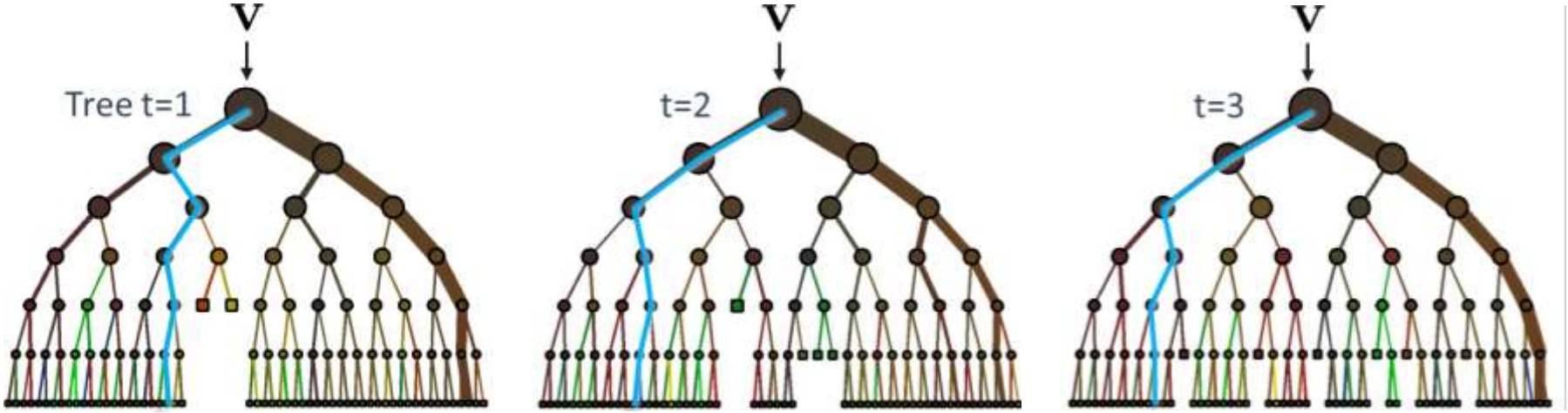
Dr. Debdoot Sheet
Assistant Professor
Department of Electrical Engineering
Indian Institute of Technology Kharagpur

www.facweb.iitkgp.ernet.in/~debdoot/

NOT ABOUT WALKING IN A FOREST



IS ALL ABOUT



Overview

- Historical Perspective
- Decision Tree
- Random Forest
- Application Scenarios
- Computational Complexity
- Variable Importance
- What's hot about them in ML Research?

Historical Perspective

Decision Trees

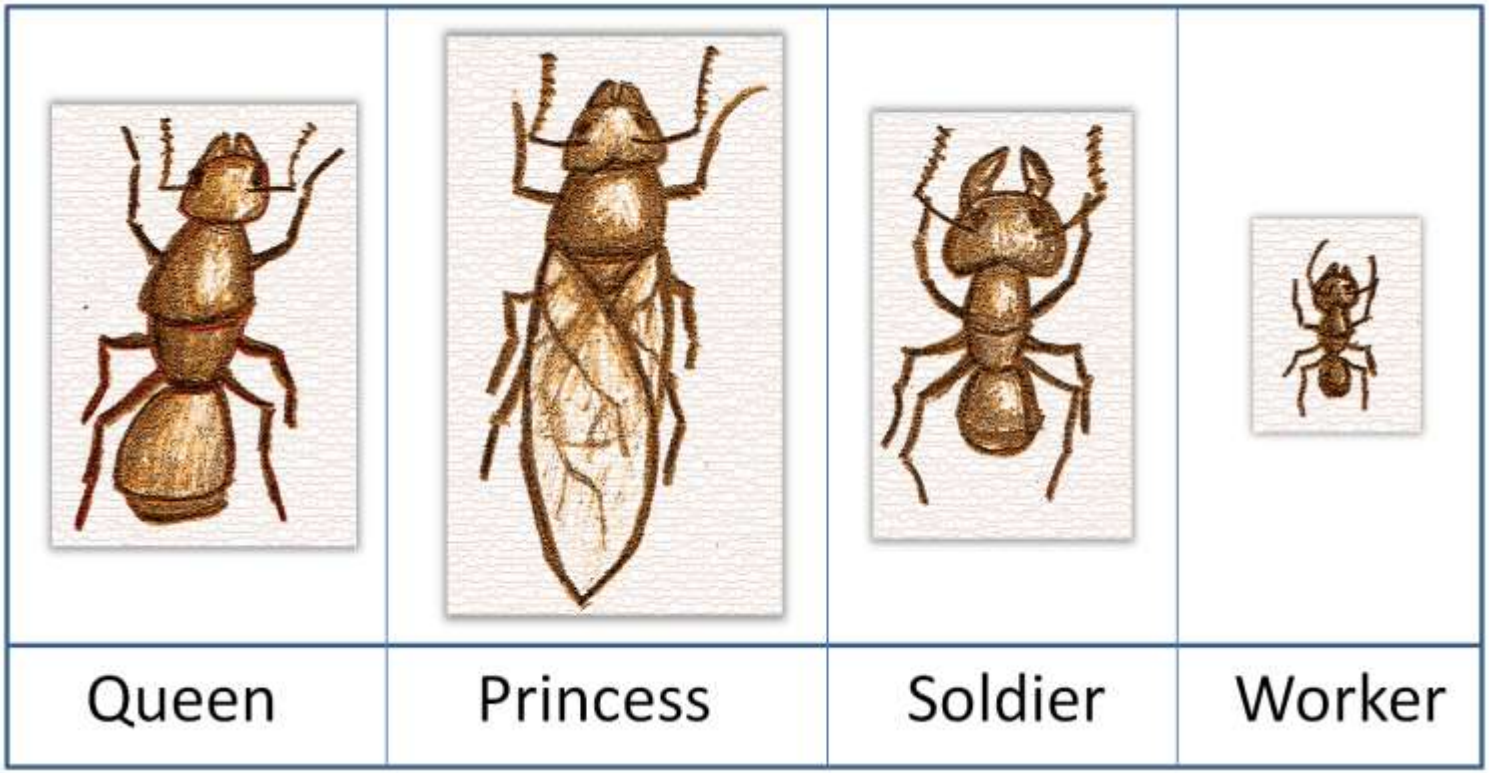
- L. Breiman, J. Friedman, C. J. Stone, and R. A. Olshen, *Classification and Regression Trees*. Chapman and Hall/CRC (SIAM), **1984**.
- J. R. Quinlan, *C4.5: Programs for Machine Learning*. **1993**.

Random Forests

- Y. Amit and D. Geman., "Shape quantization and recognition with randomized trees," *Neural Computation,* vol. 9, pp. 1545–1588, **1997**.
- T. K. Ho, "The random subspace method for constructing decision forests," *IEEE T-PAMI,* vol. 20, no. 8, pp. 832–844, **1998**.
- L. Breiman, "Random forests," *Machine Learning,* vol. 45, no. 1, pp. 5–32, **2001**.

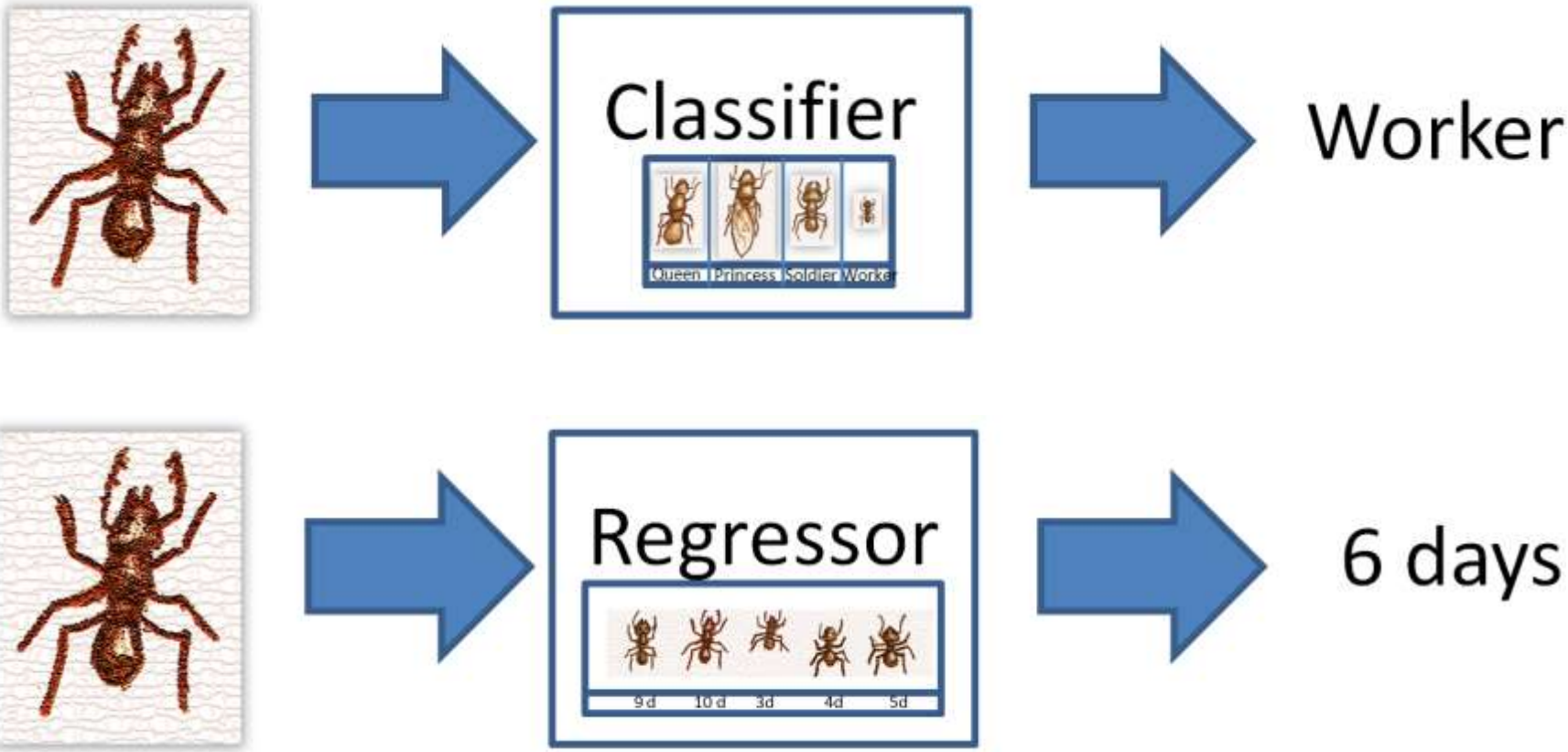
DECISION TREE

Problem Statement

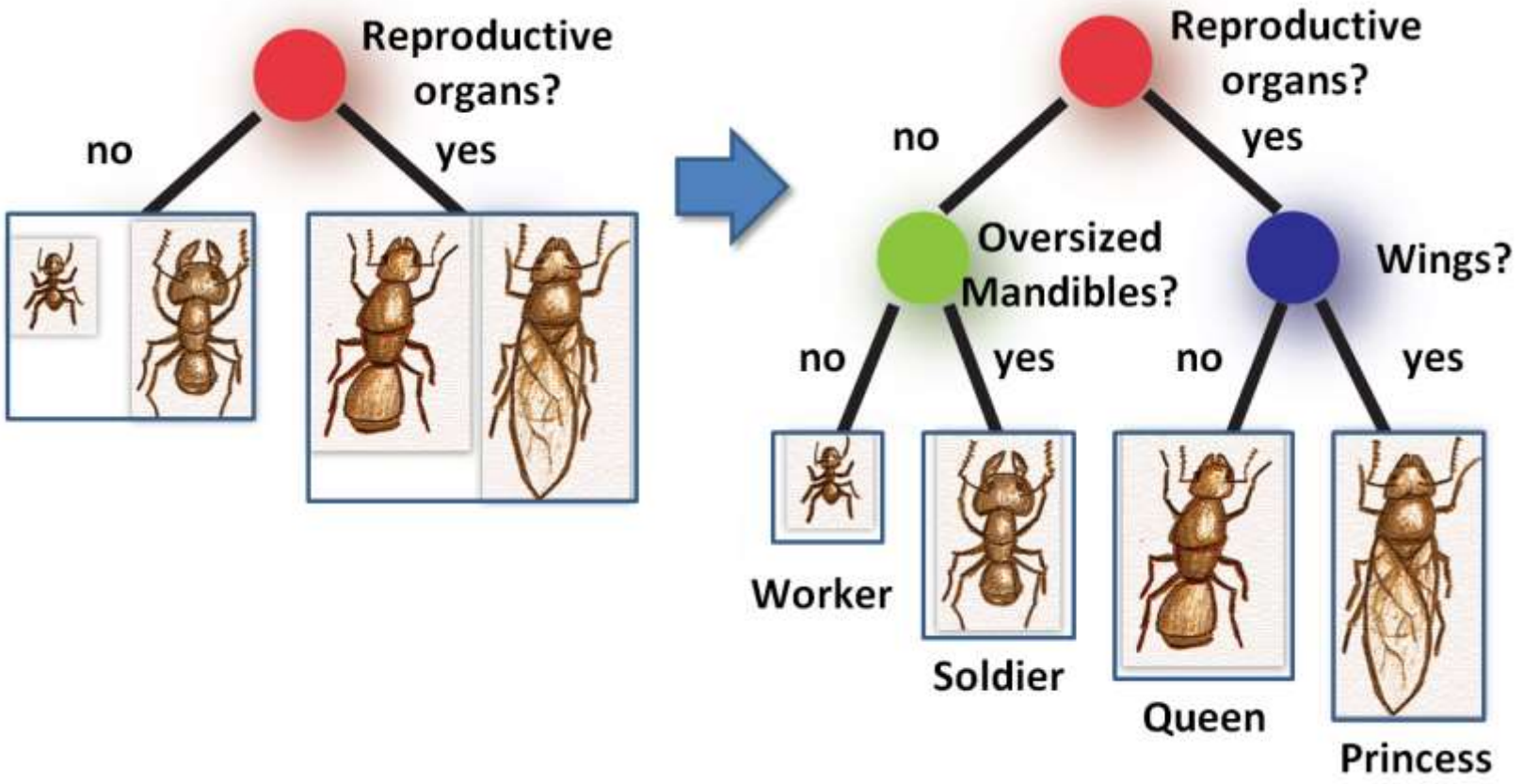


Formica rufa (Red wood ant)

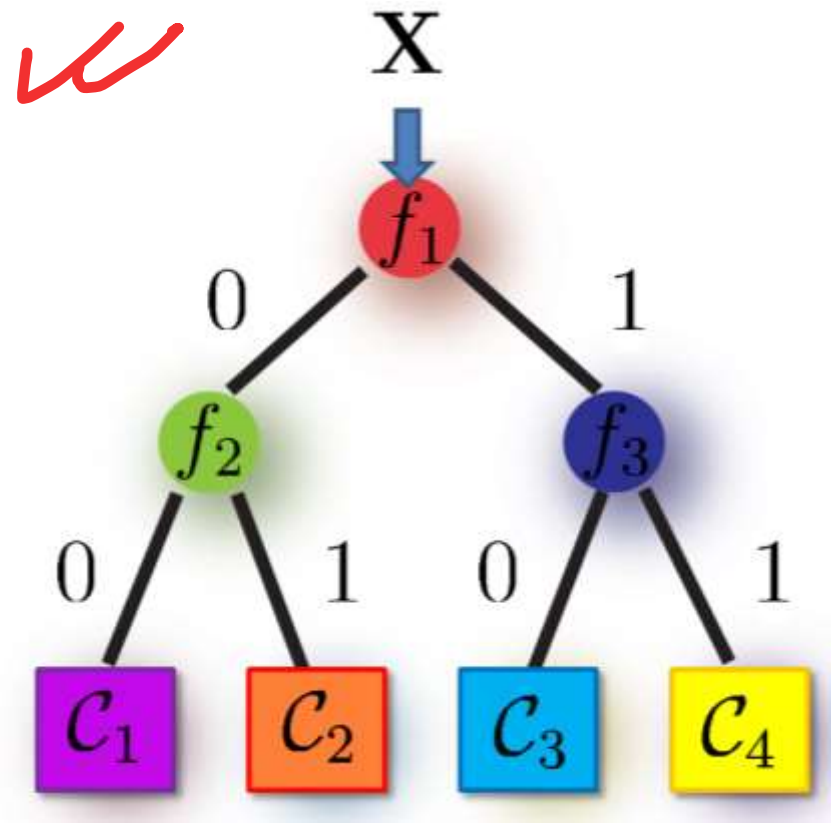
Classification vs. Regression

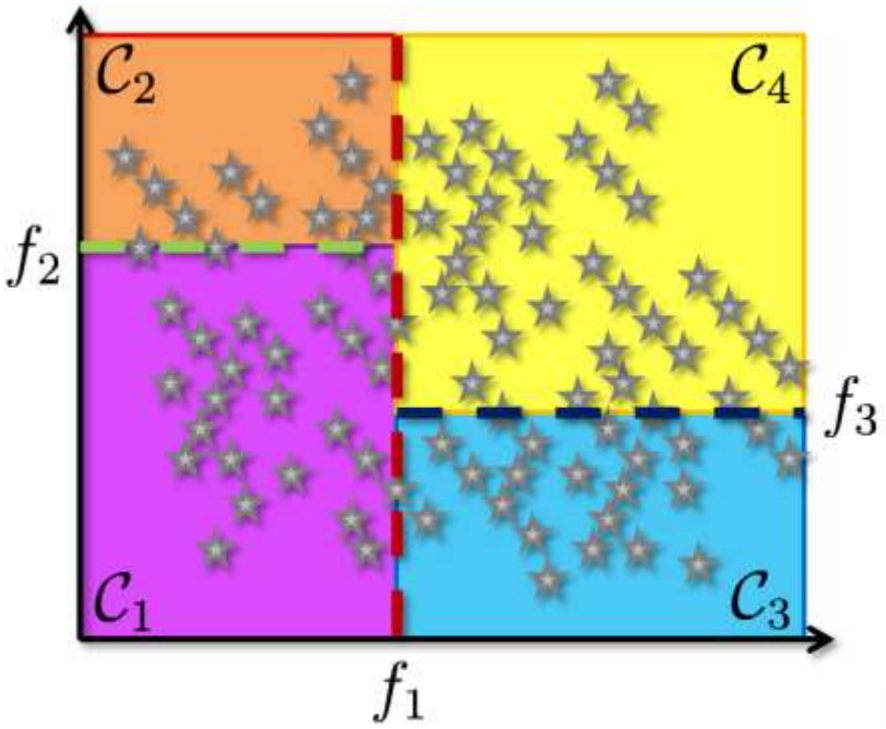


Decision Tree

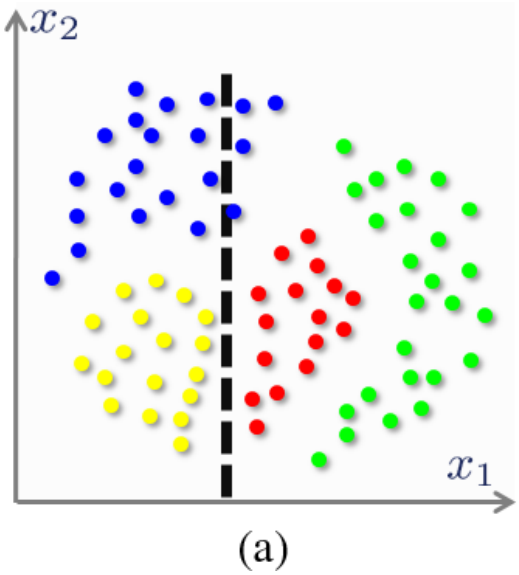


Forming a Decision Tree



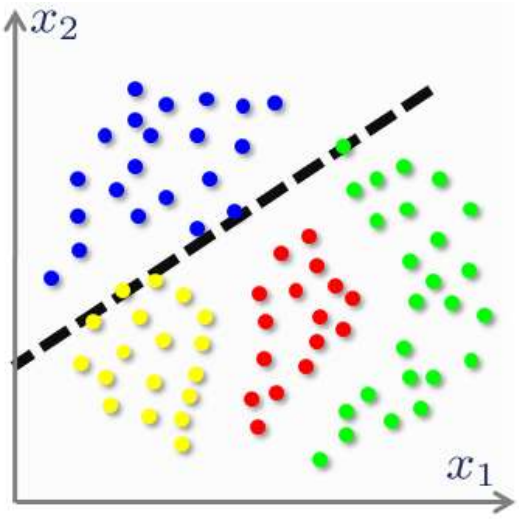


Step 1: Split Function at Node



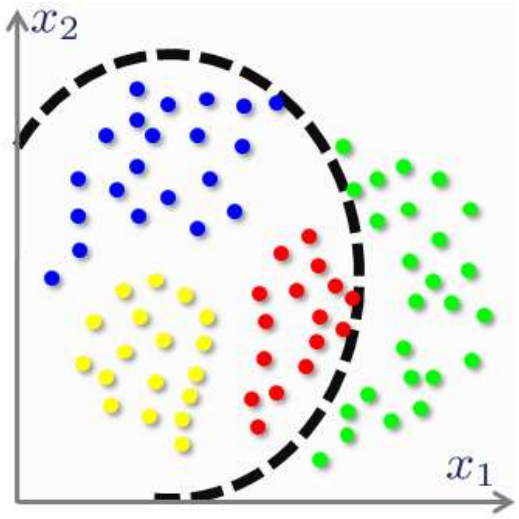
(a)

Axis aligned split



(b)

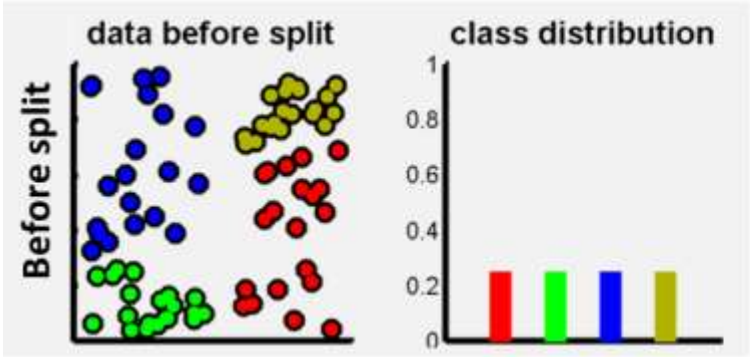
Oblique split



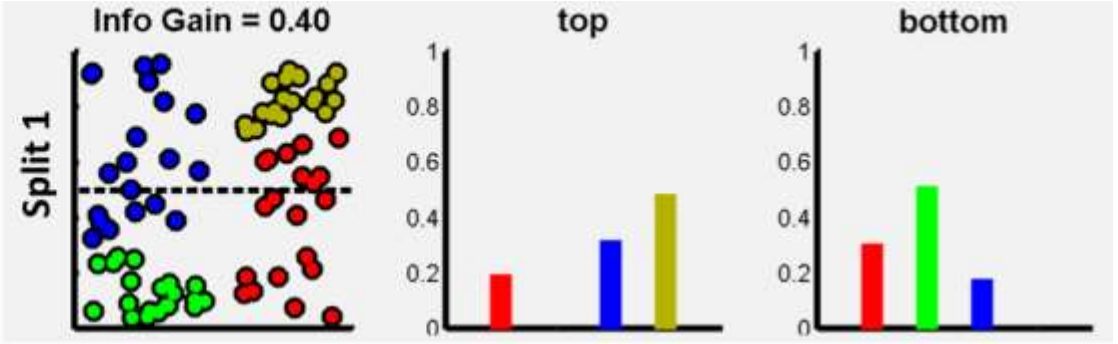
(c)

Polynomial split

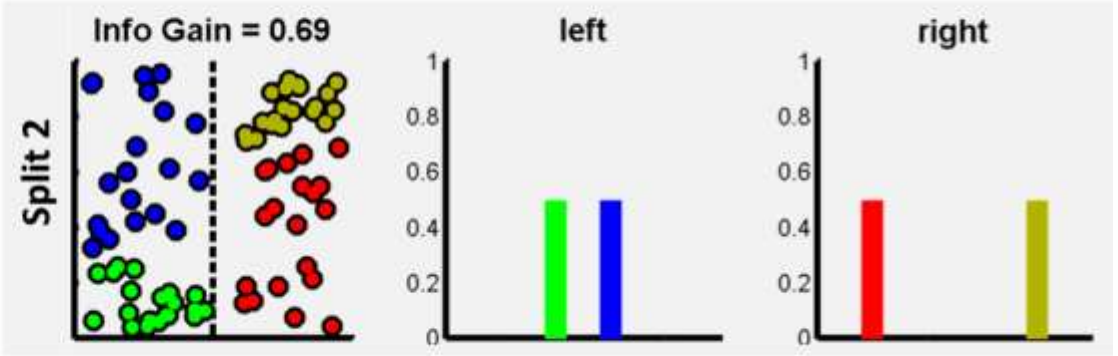
Step 2: Assessing Purity of Split



(a)

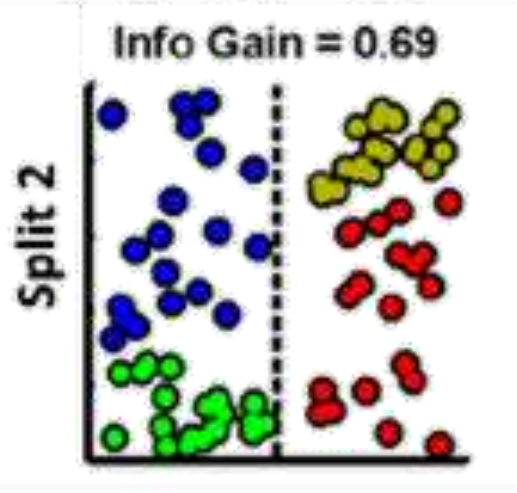


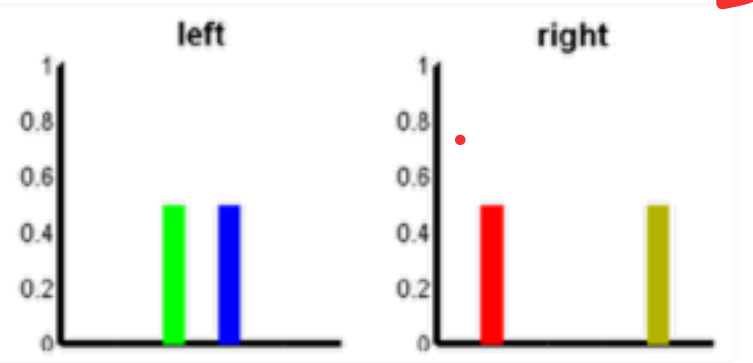
(b)



(c)

Cost function for Split Purity





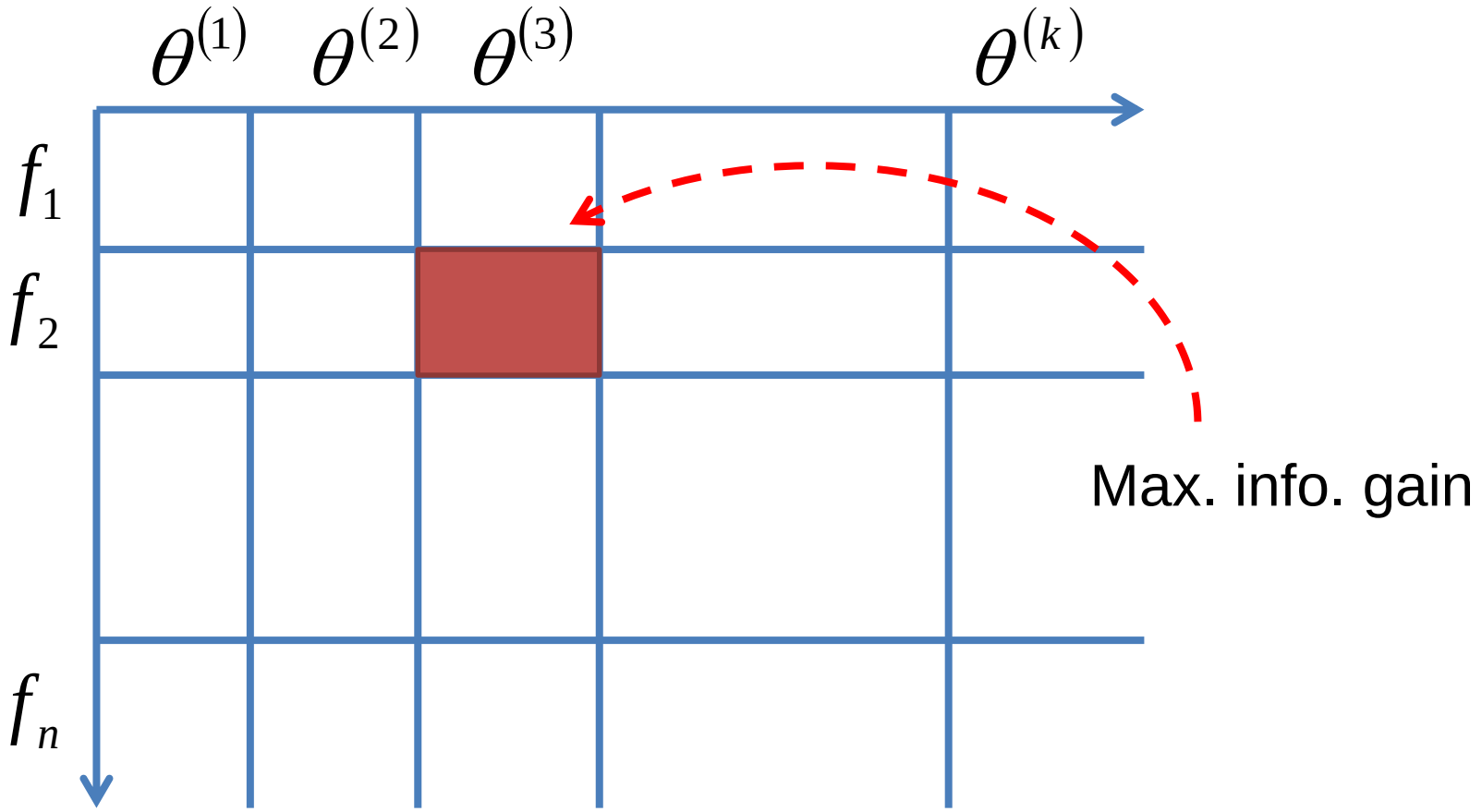
Entropy of class distribution

$$H(\mathcal{S}) = -\sum_{c \in \mathcal{C}} p(c) \log(p(c)).$$

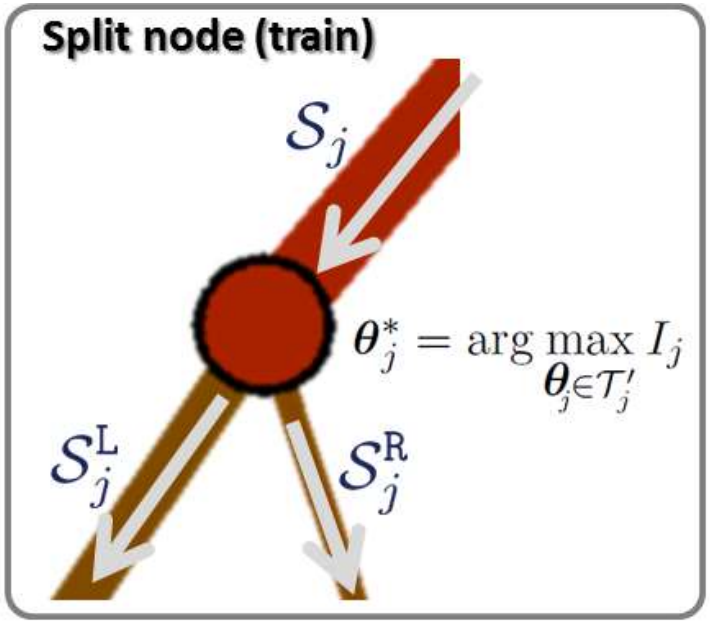
Information Gain

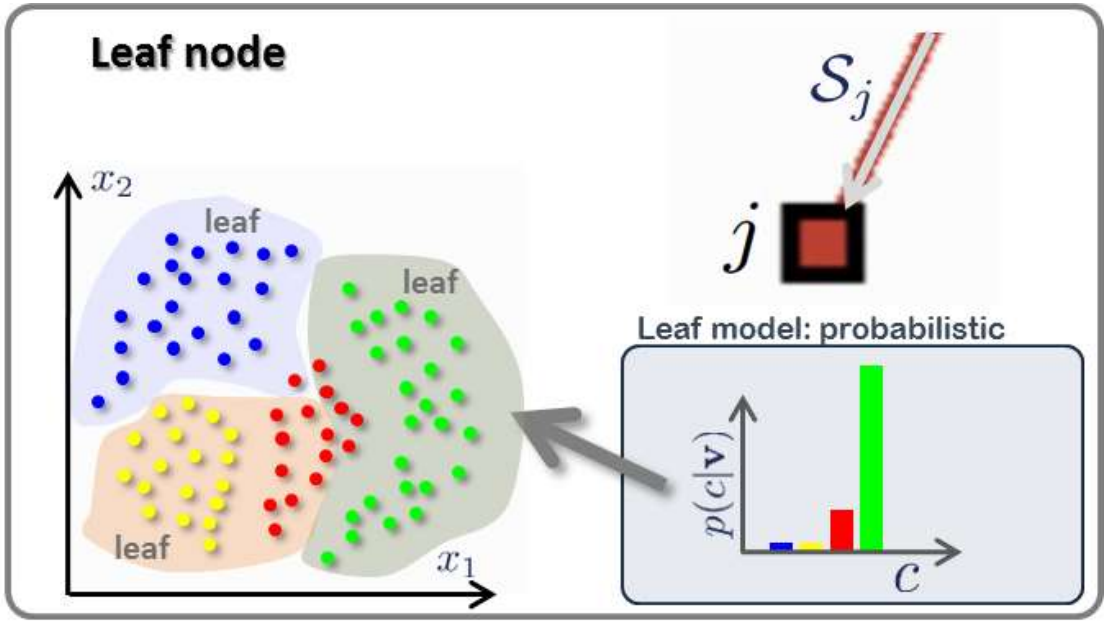
$$I = H(\mathcal{S}) - \sum_{i \in \{L,R\}} \frac{|\mathcal{S}^i|}{|\mathcal{S}|} H(\mathcal{S}^i).$$

Step 3: Selecting Optimum Split

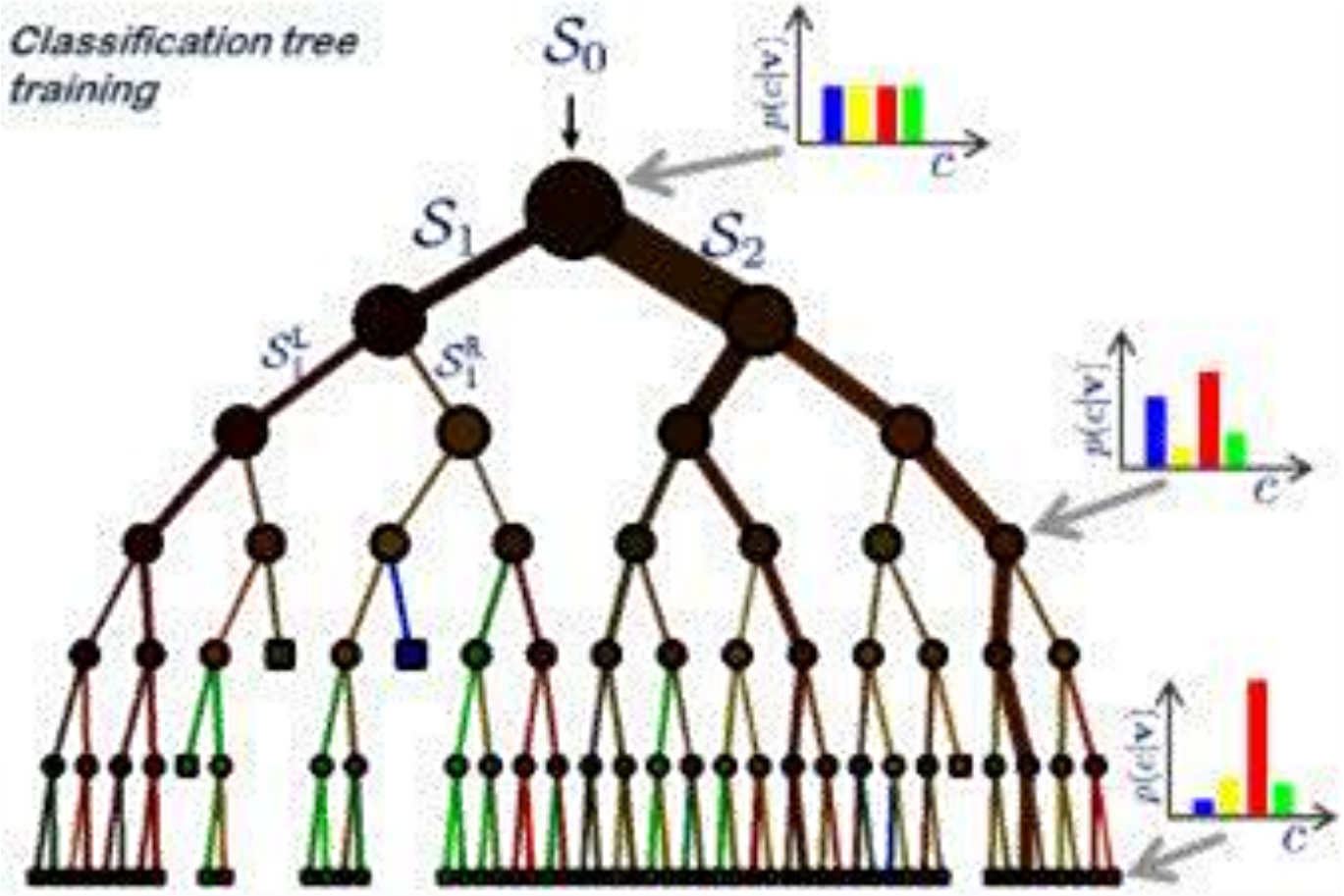


Step 4: Stopping Criteria

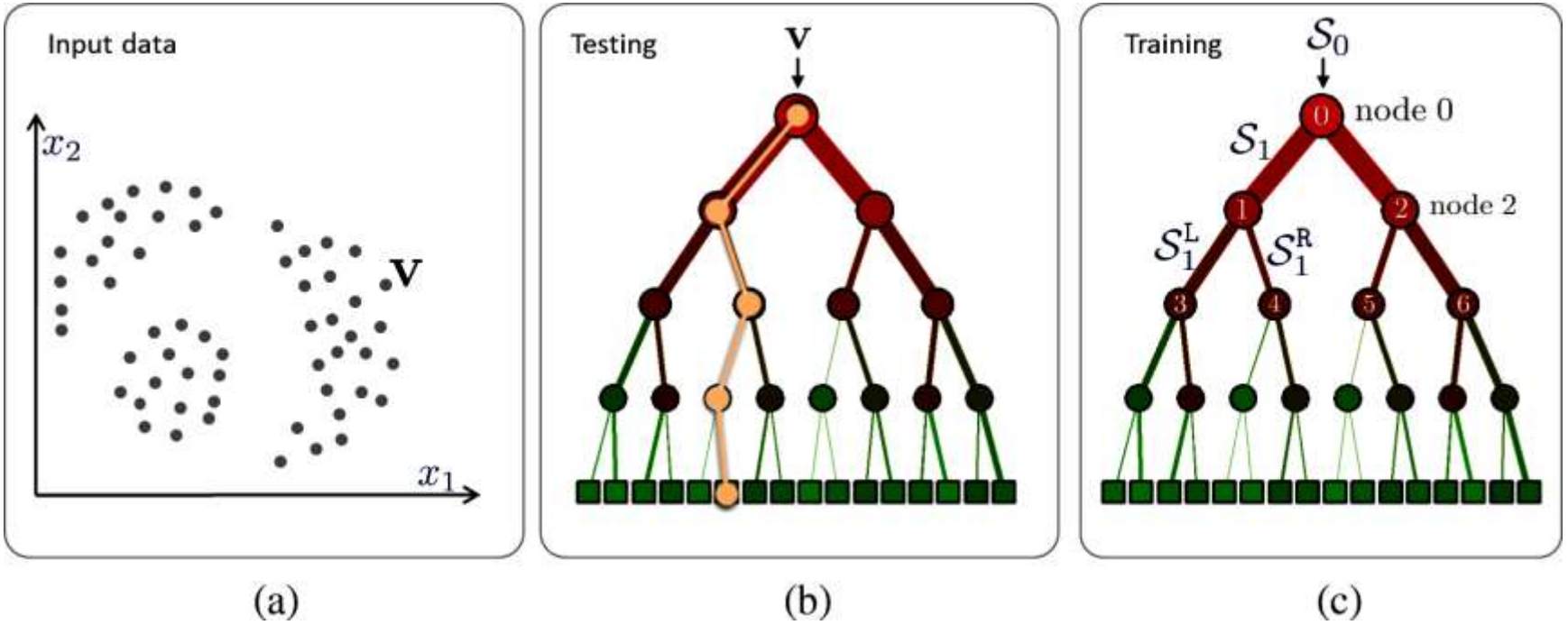




Step 5: Leaf Prediction Model

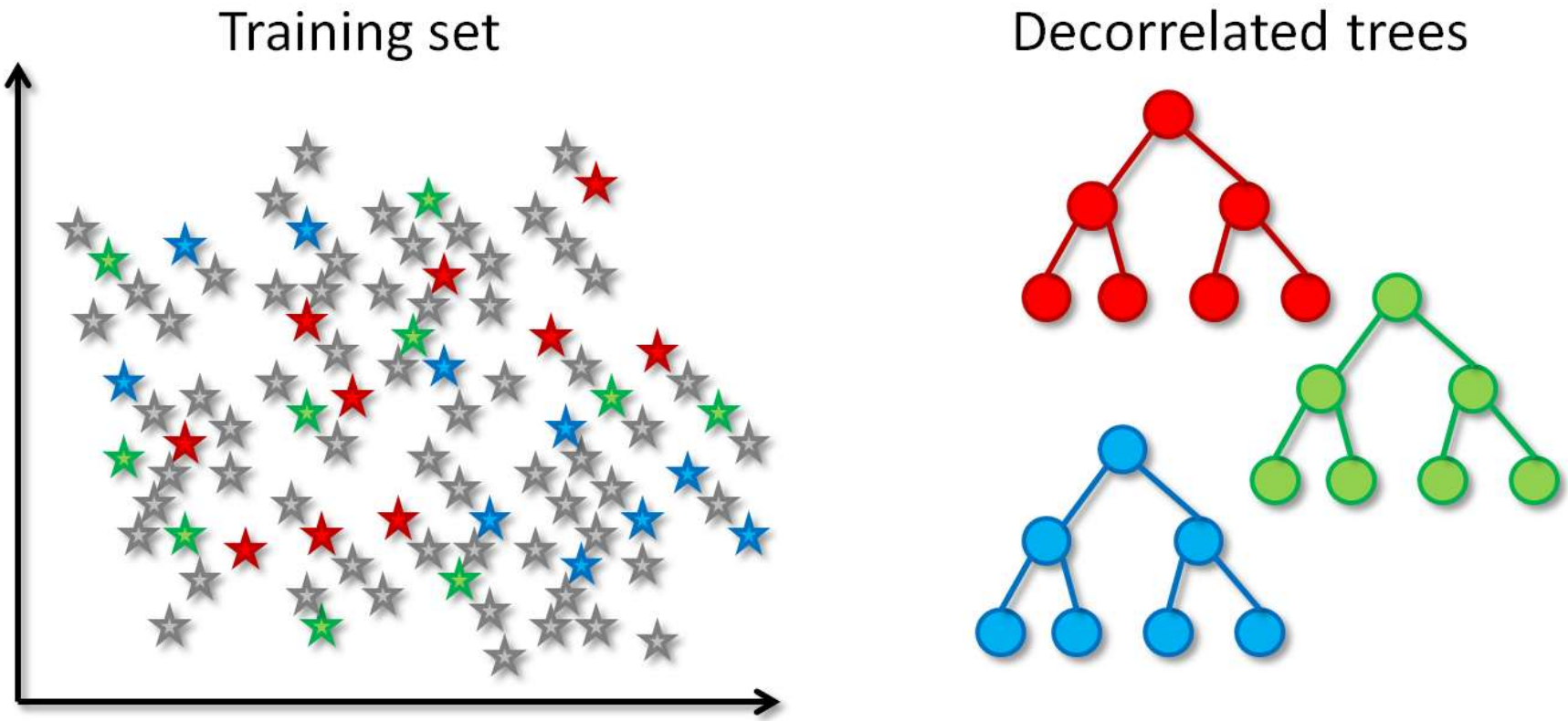


Deploying a Decision Tree



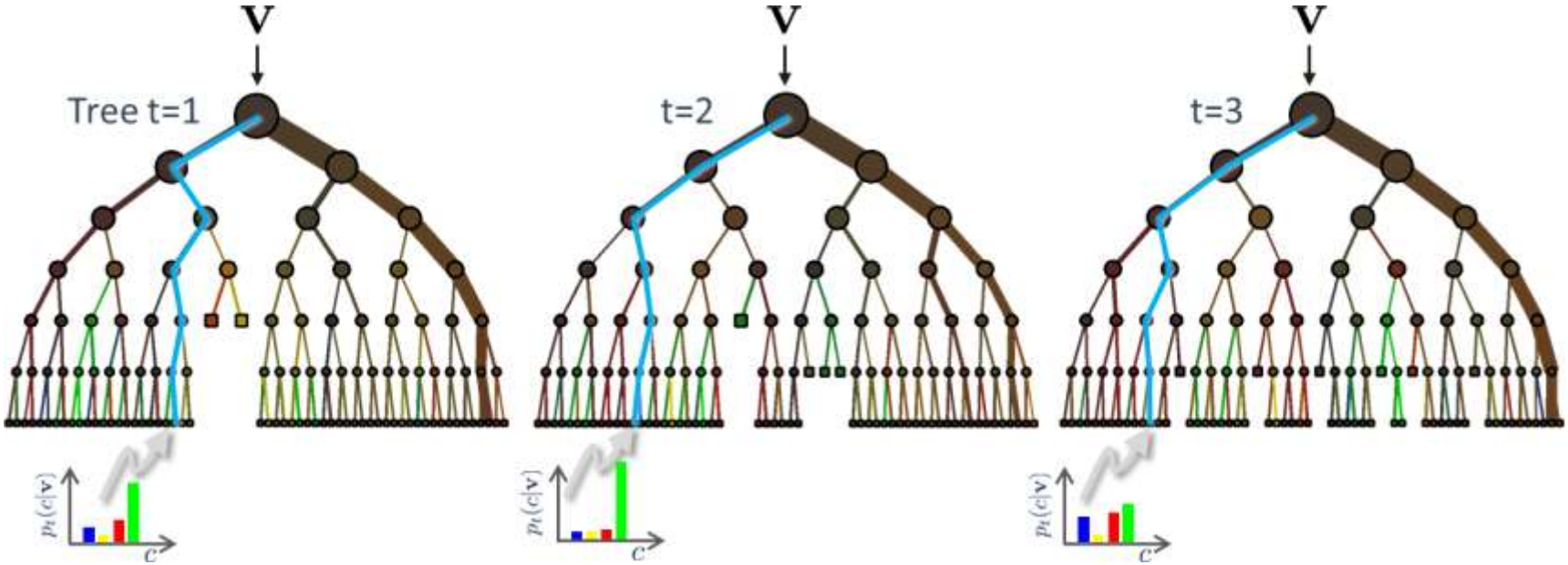
RANDOM FOREST

Growing Multiple Trees in a Forest



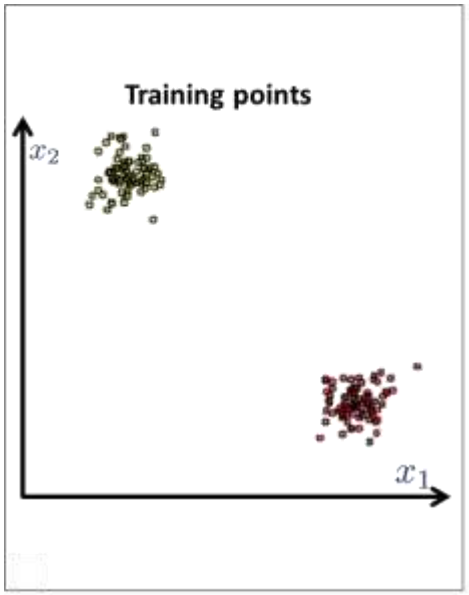
Bagging – Bootstrapped Aggregation

Ensemble Prediction Model

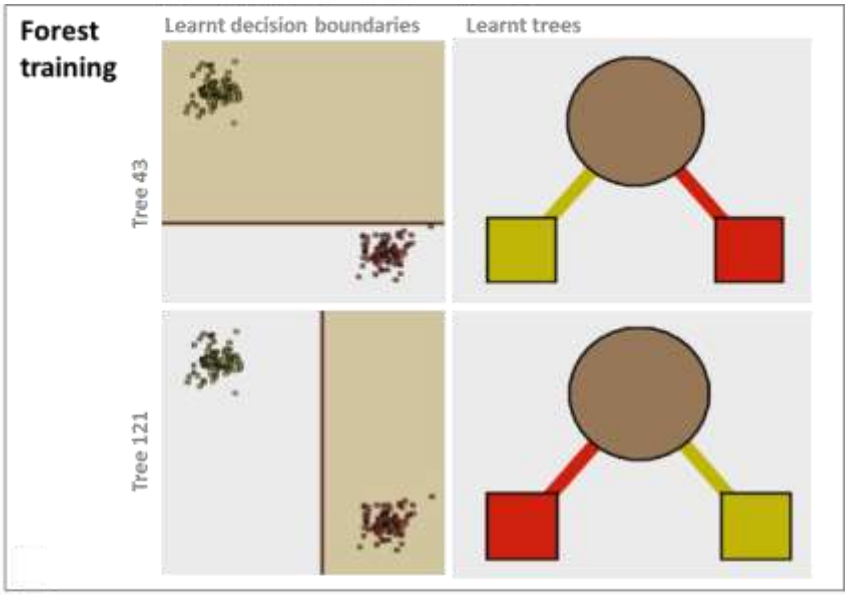


$$p(c|\mathbf{v}) = \frac{1}{T}\sum_{t}^{T} p_t(c|\mathbf{v})$$

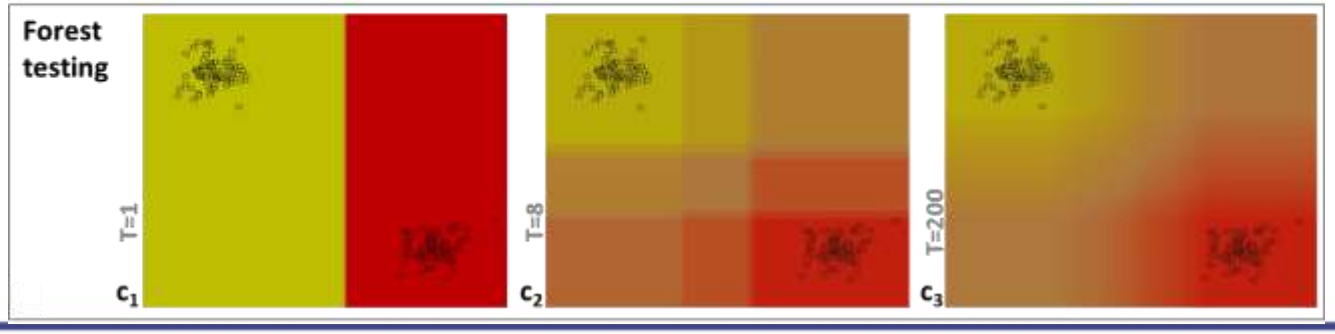
What do we gain by using a Forest?



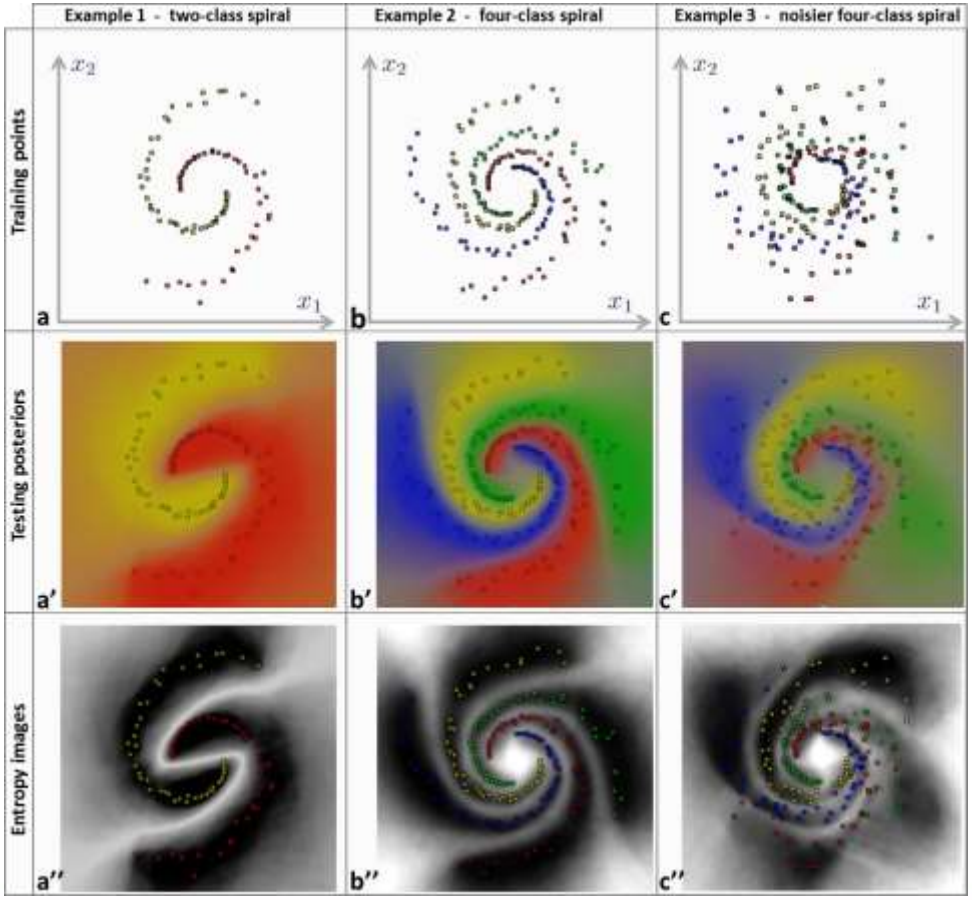
(a)



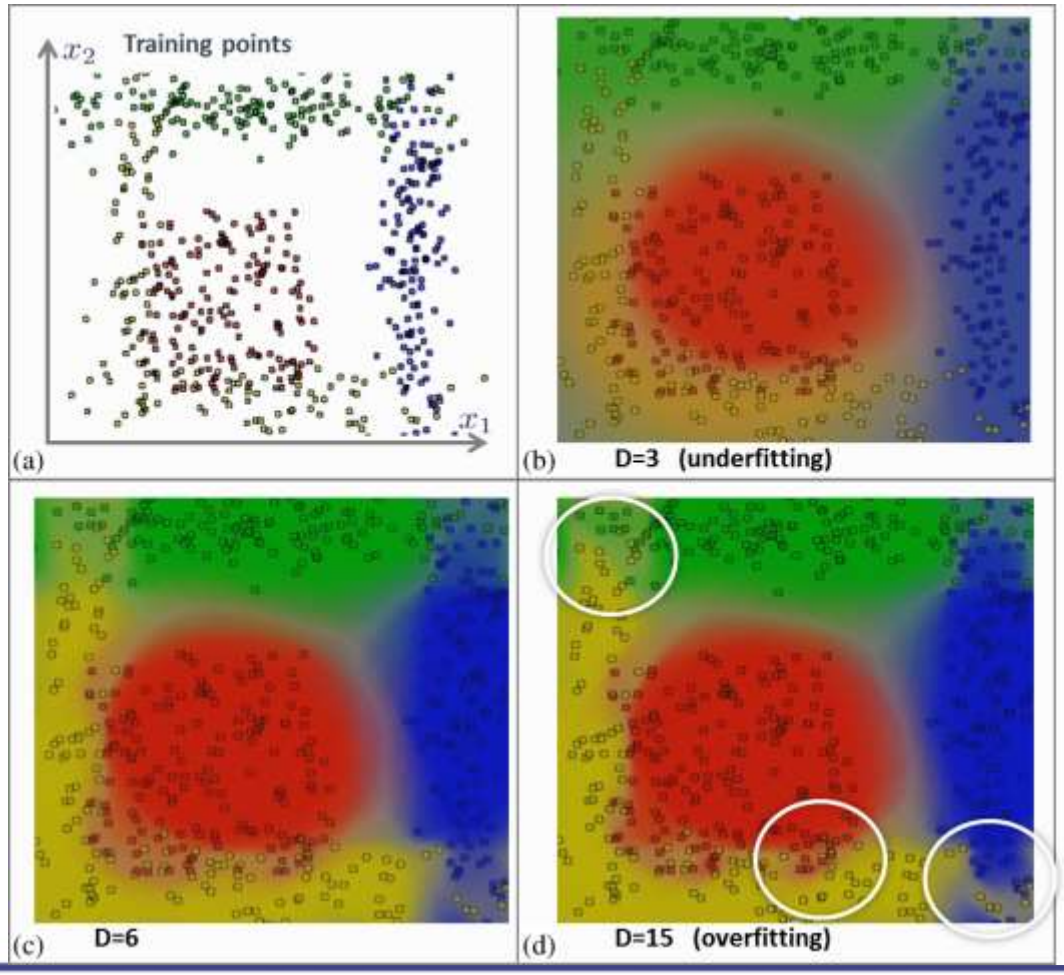
(b)



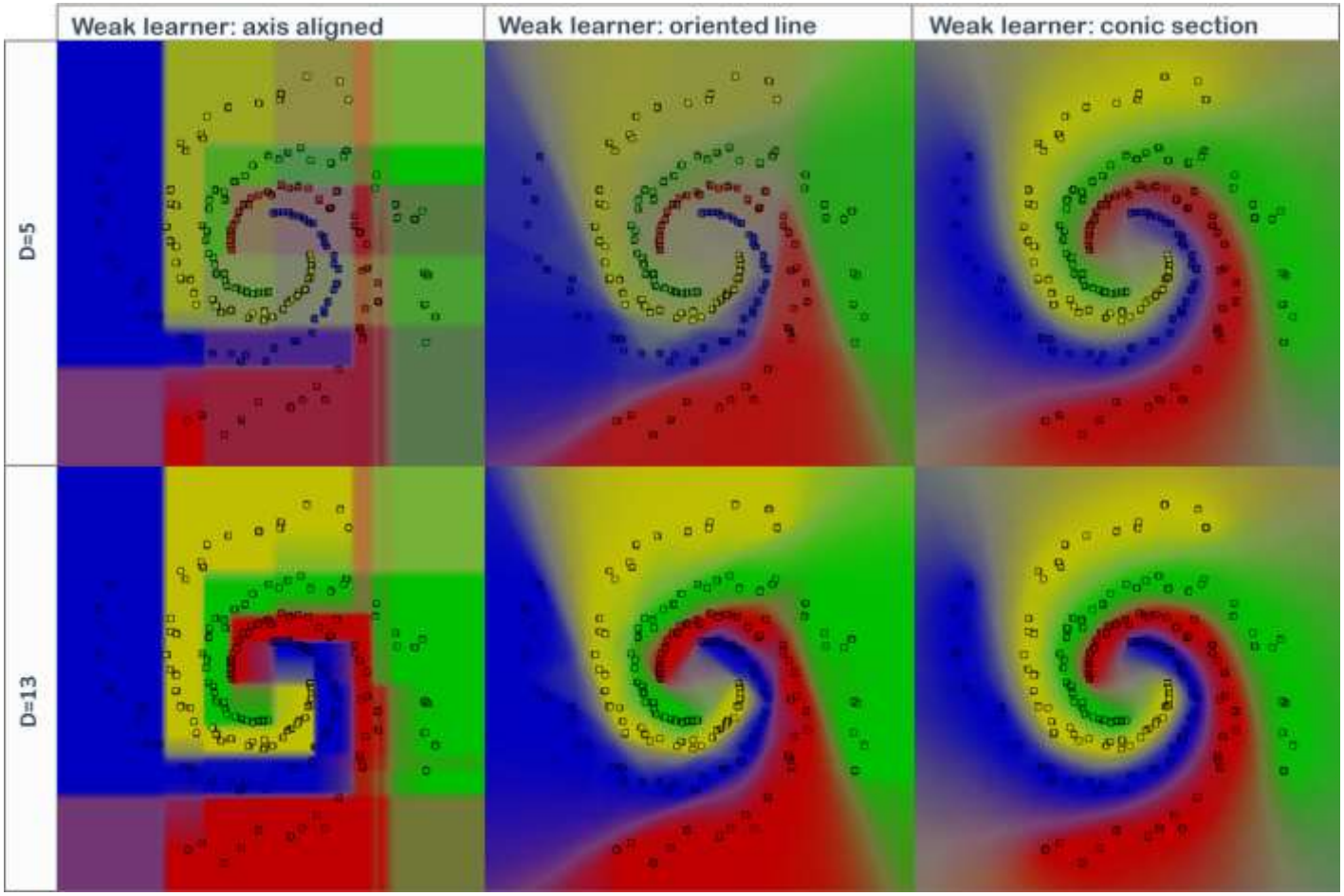
Noise Resilience and Topology Independence



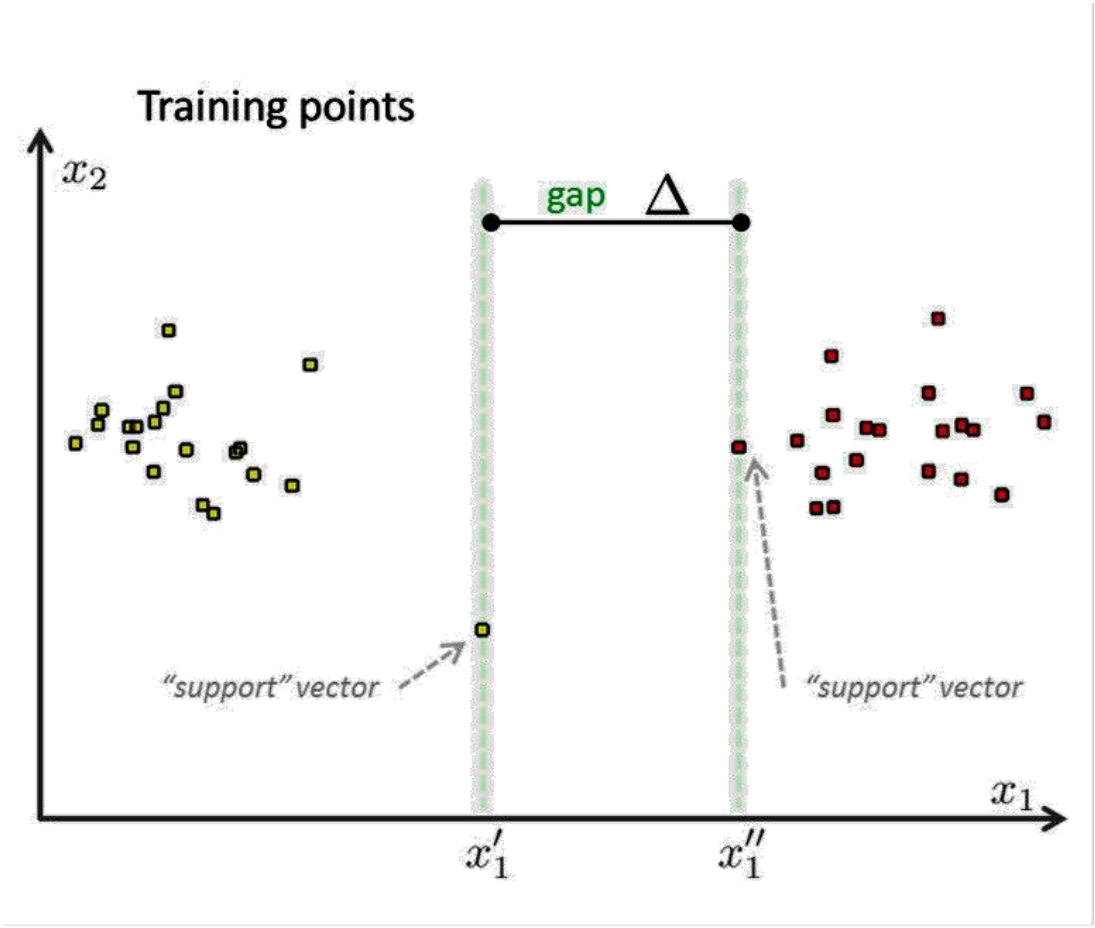
Effect of Tree Depth

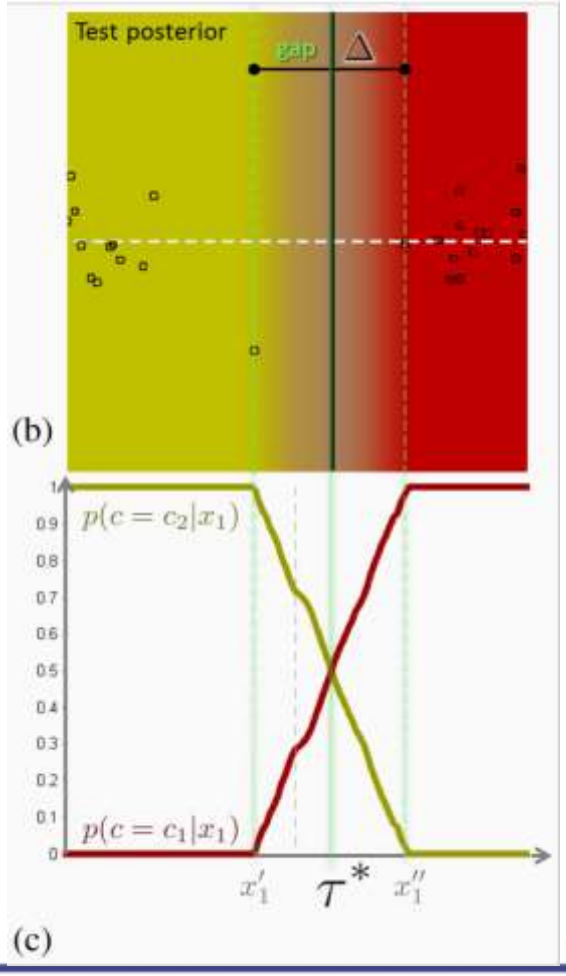


Effect of Split Function

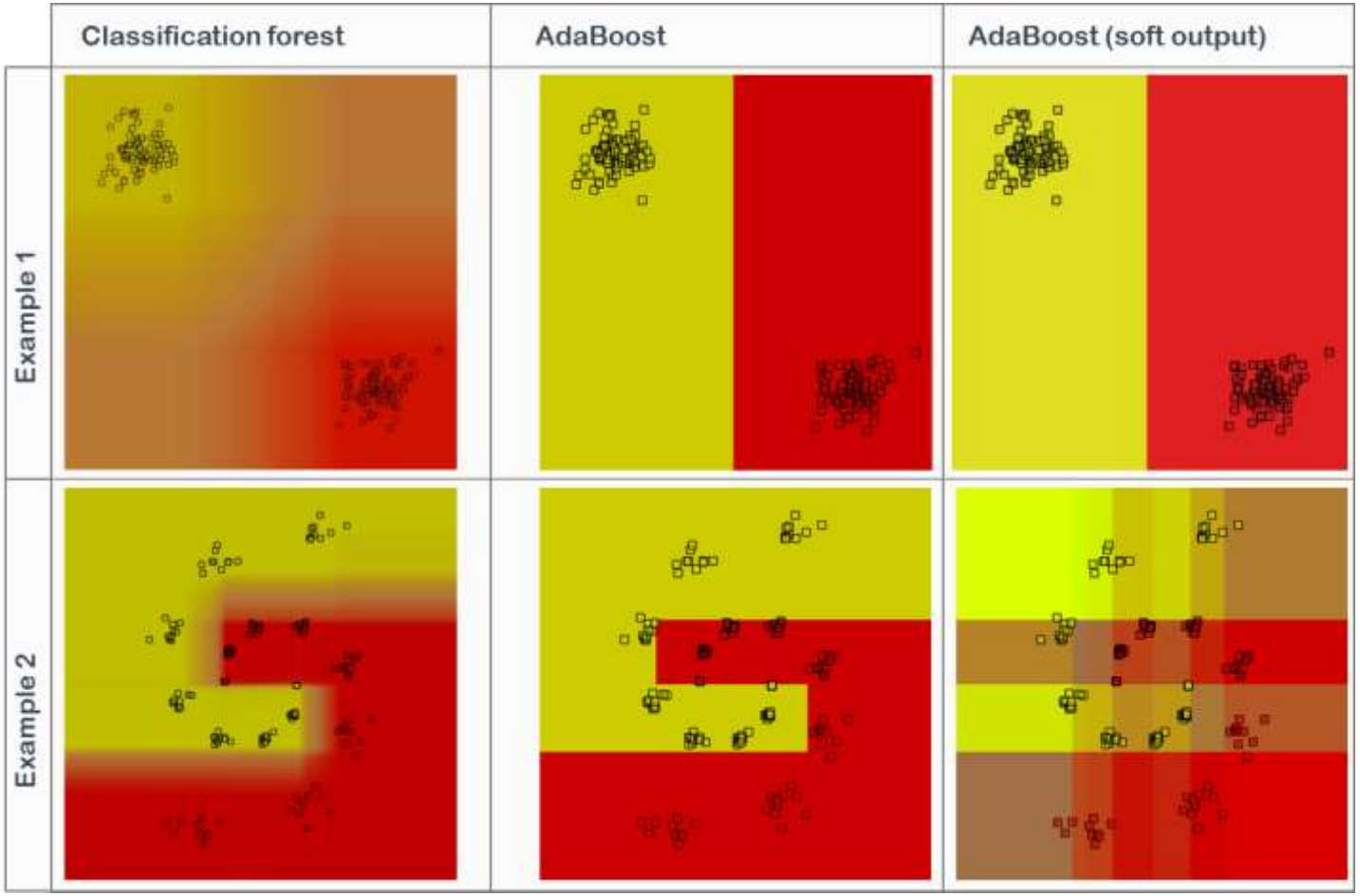


Classification Margin

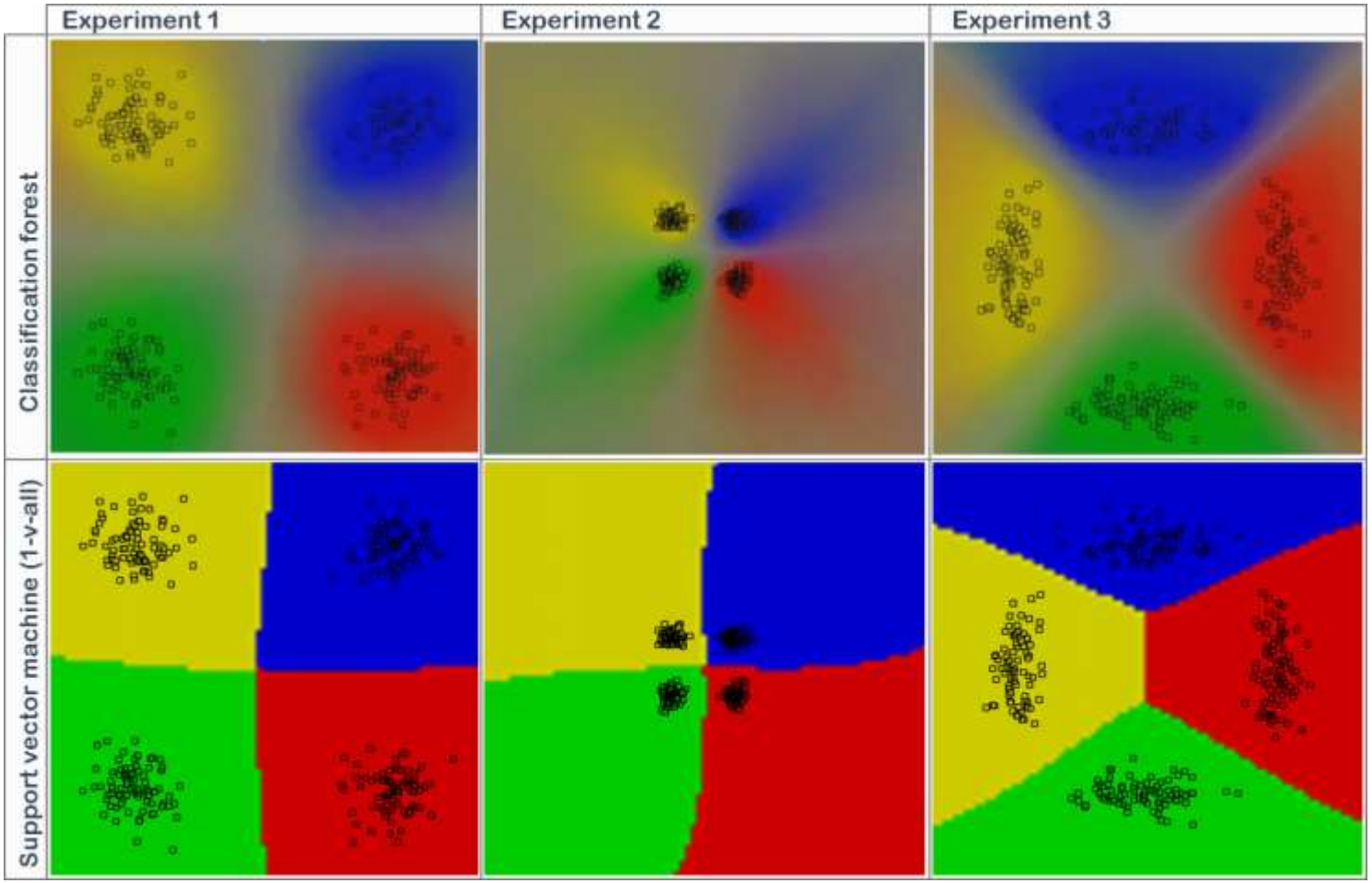




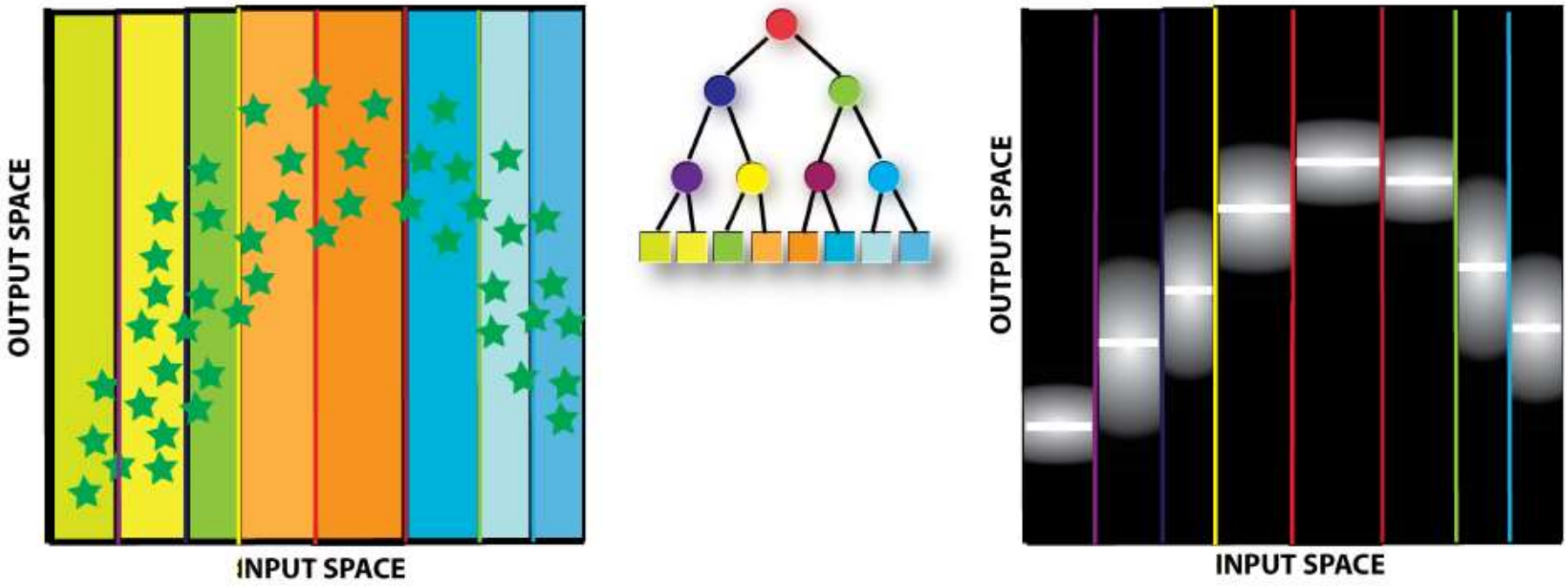
Random Forest vs. AdaBoost



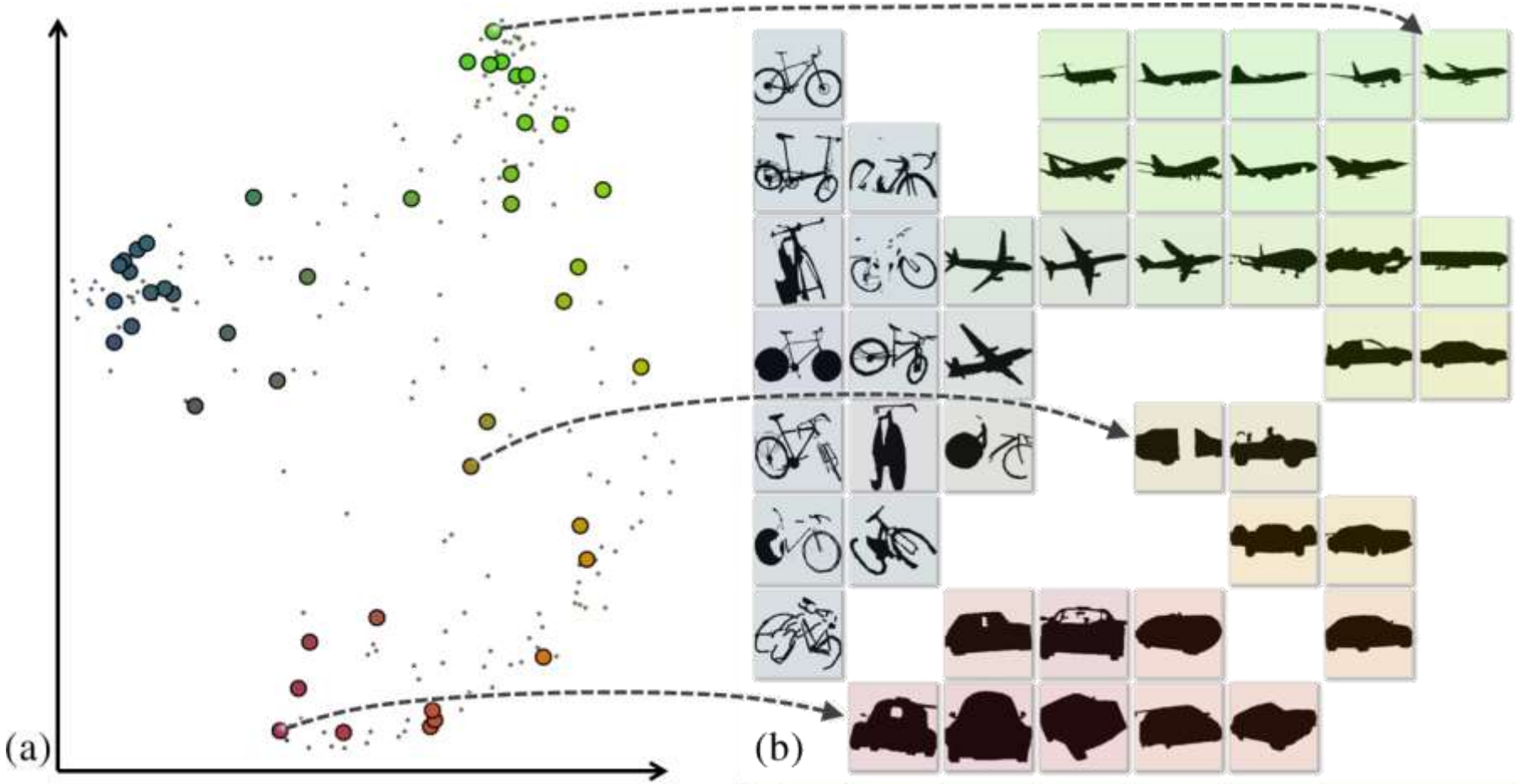
Random Forest vs. SVM



Regression Forest



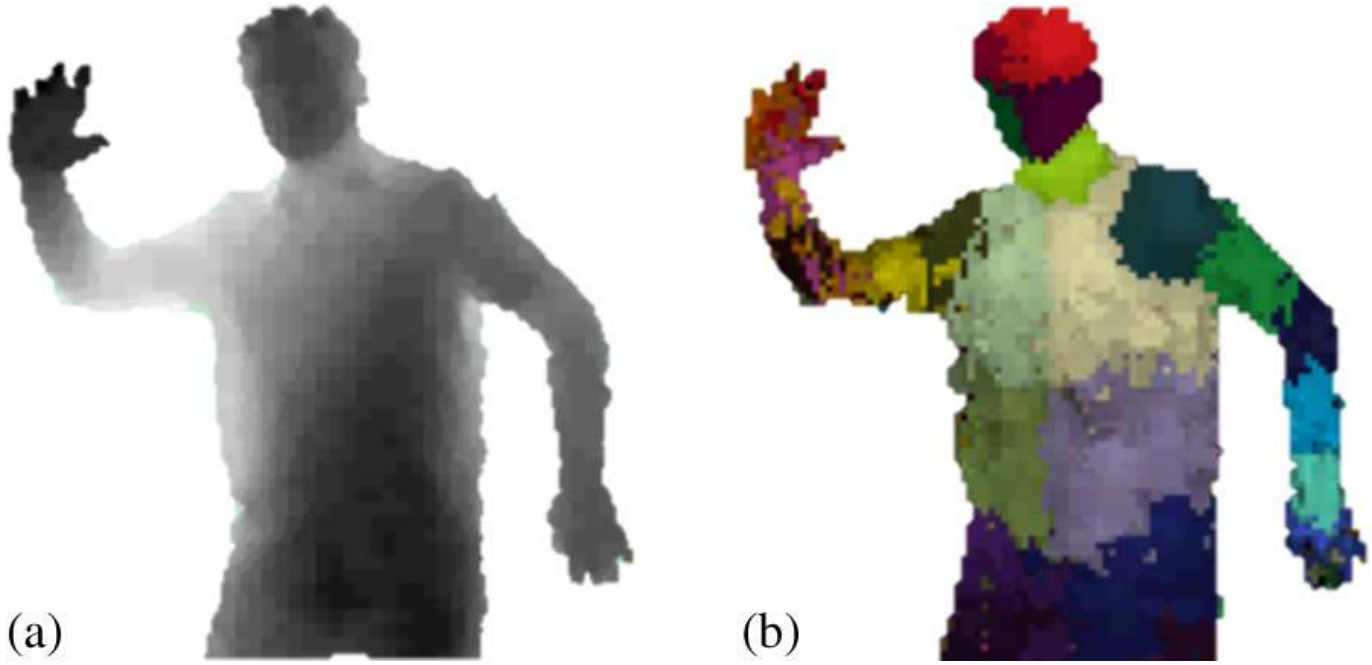
Manifold Forest



After the Brainstorming (Break)!

APPLICATION SCENARIOS

Gaming – Kinect for Xbox 360

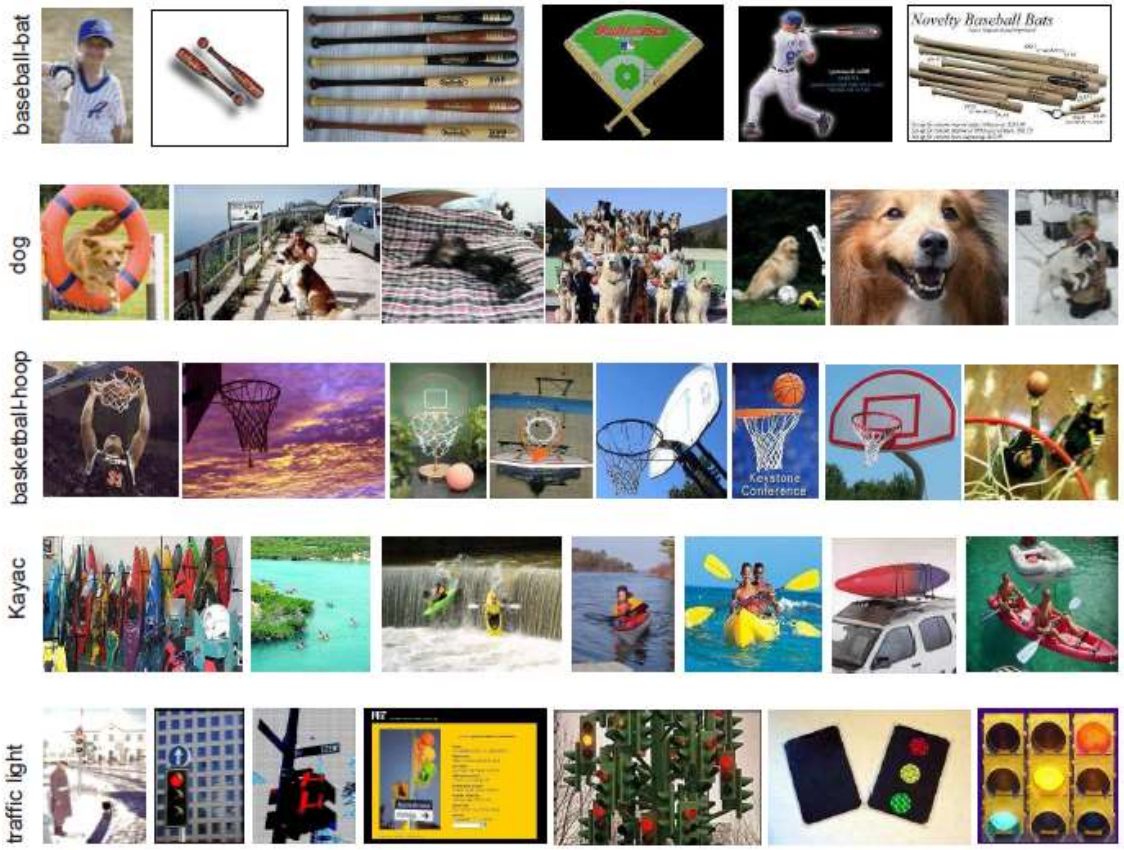


Depth map

Body part classification

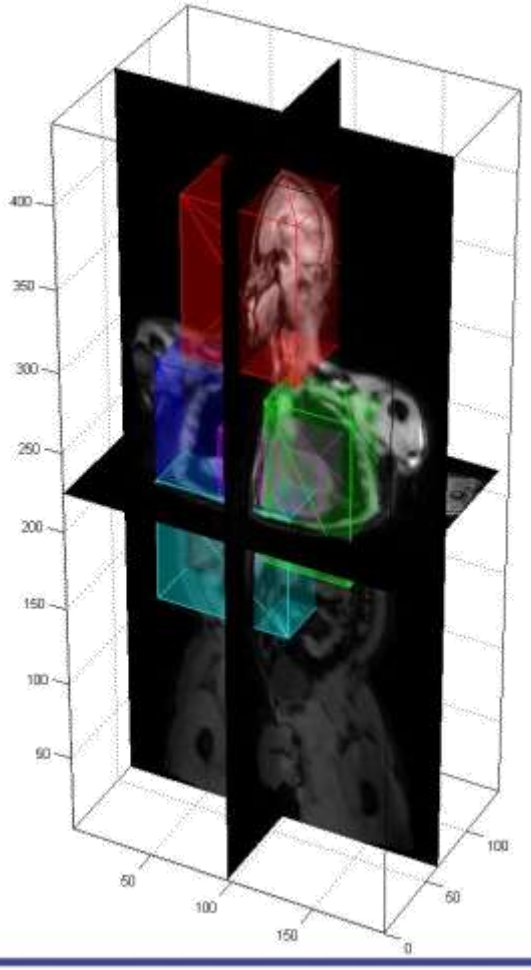
J. Shotton, A. Fitzgibbon, M. Cook, T. Sharp, M. Finocchio, R. Moore, A. Kipman, and A. Blake, "Real-time human pose recognition in parts from a single depth image," in *Proc. CVPR, 2011.*

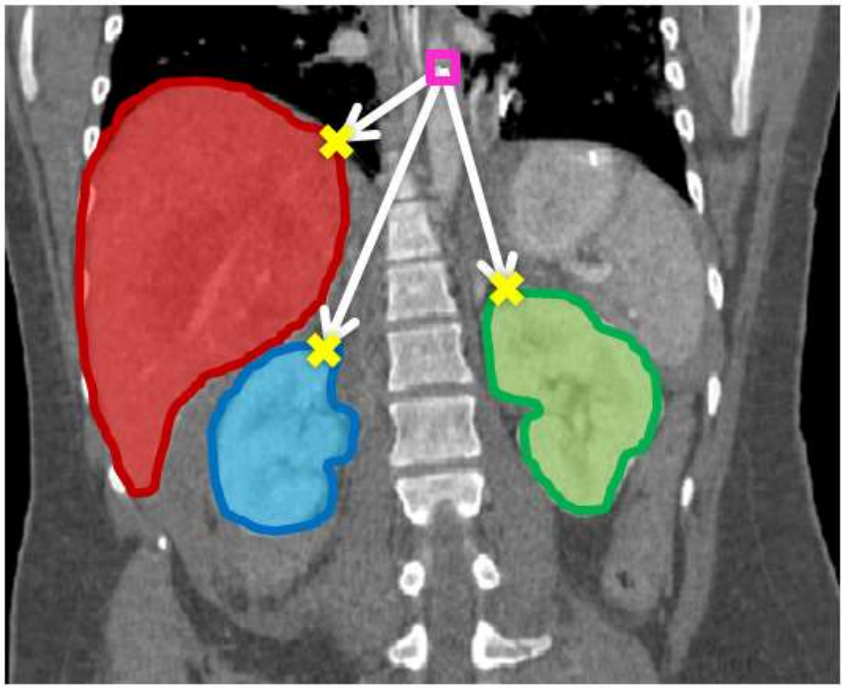
Vision – Scene Classification



Bosch, A., Zisserman, A., & Muoz, X. “Image classification using random forests and ferns”, *ICCV 2007.*

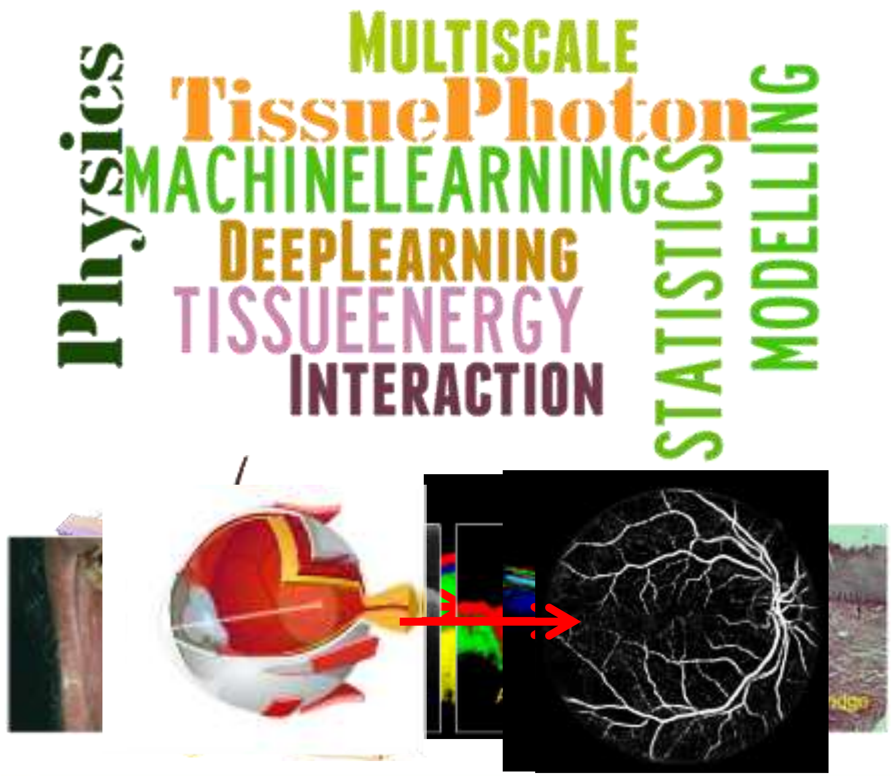
Medical – Digital Anatomy





A. Criminisi, D. Robertson, E. Konukoglu, J. Shotton, S. Pathak, S. White, and K. Siddiqui, "Regression Forests for Efficient Anatomy Detection and Localization in Computed Tomography Scans", *Medical Image Analysis*, 2013

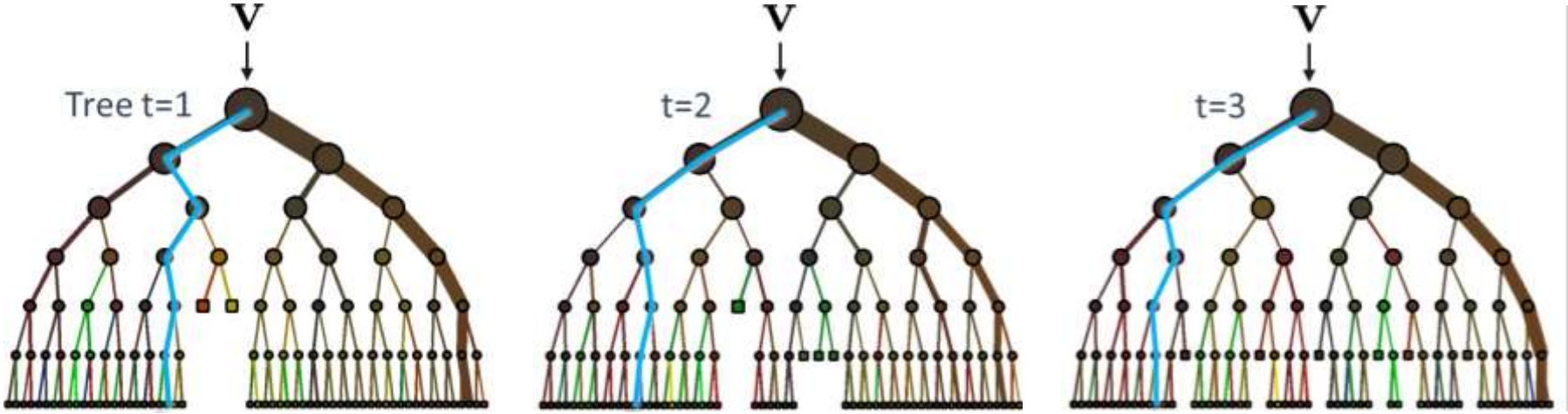
Medical – Computational Histology



- D. Sheet, et al., "Joint learning of ultrasonic backscattering statistical physics and signal confidence primal for characterizing atherosclerotic plaques using intravascular ultrasound", *Med. Image Anal.*, 18(1), 2014
- D. Sheet, et al., "Transfer Learning of Tissue Photon Interaction in Optical Coherence Tomography towards In vivo Histology of the Oral Mucosa", *Proc. Int. Symp. Biomed. Imaging (ISBI)*, 2014.
- K. Basak and D. Sheet et al., "Learning of Tissue Photon Interaction in Laser Speckle Contrast Imaging for Label-free Retinal Angiography", *Int. Symp. Biomed. Imaging (ISBI)*, 2014
- Hunting for necrosis in the shadows of intravascular ultrasound, *CMIG*, 38(2), 2014
- SPK Karri and D. Sheet, et al., "Computational Histology of Retina through Transfer Learning of Tissue Photon Interaction in Optical Coherence Tomography", *Int. Symp. Biomed. Imaging (ISBI)*, 2014.
- SPK Karri and D. Sheet, et al., "Deep Learnt Random Forests for Segmentation of Retinal Layers in Optical Coherence Tomography"
- D. Sheet et al., "Iterative self-organizing atherosclerotic tissue labeling in intravascular ultrasound images and comparison with virtual histology", *IEEE TBME*, 59(11), 2012

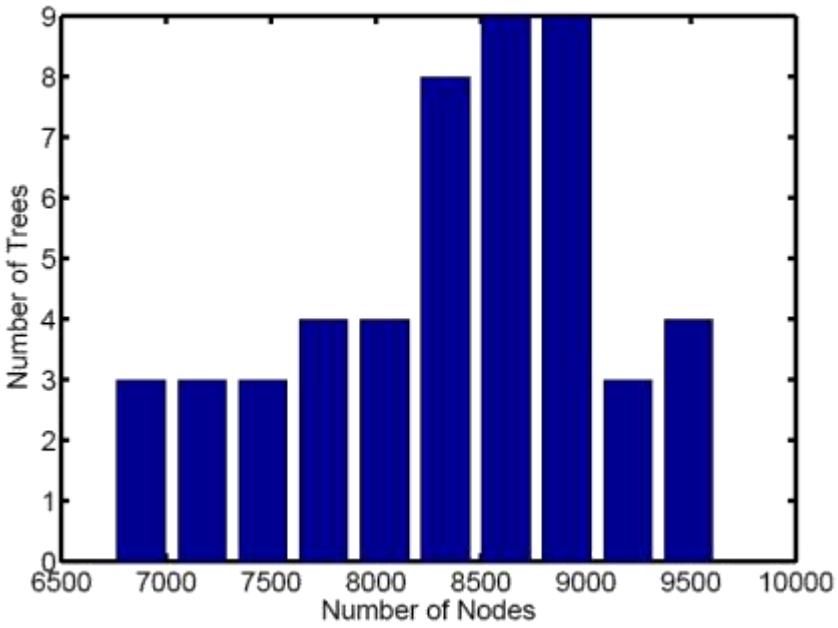
ENGINEERING DESIGN PERSPECTIVE

Understanding Computations

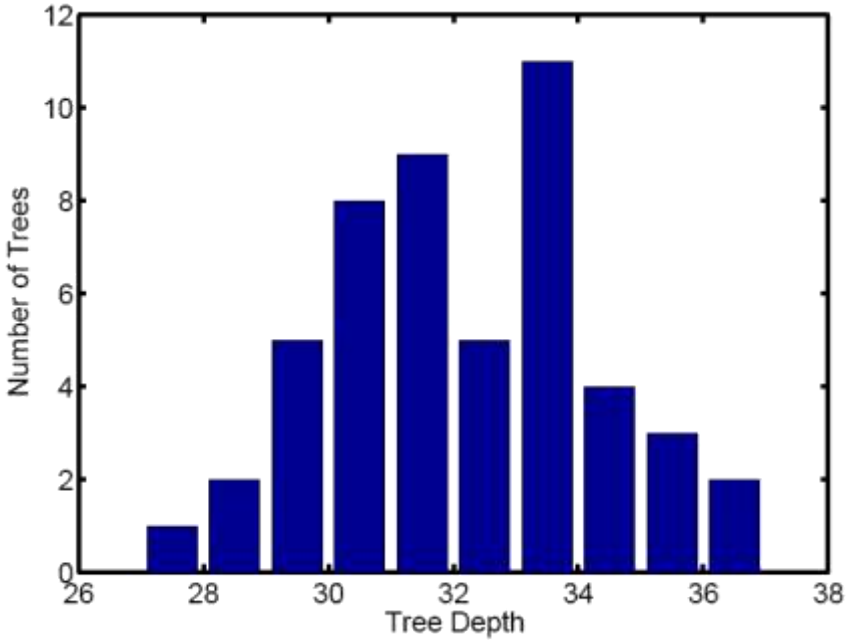


Computational Complexity

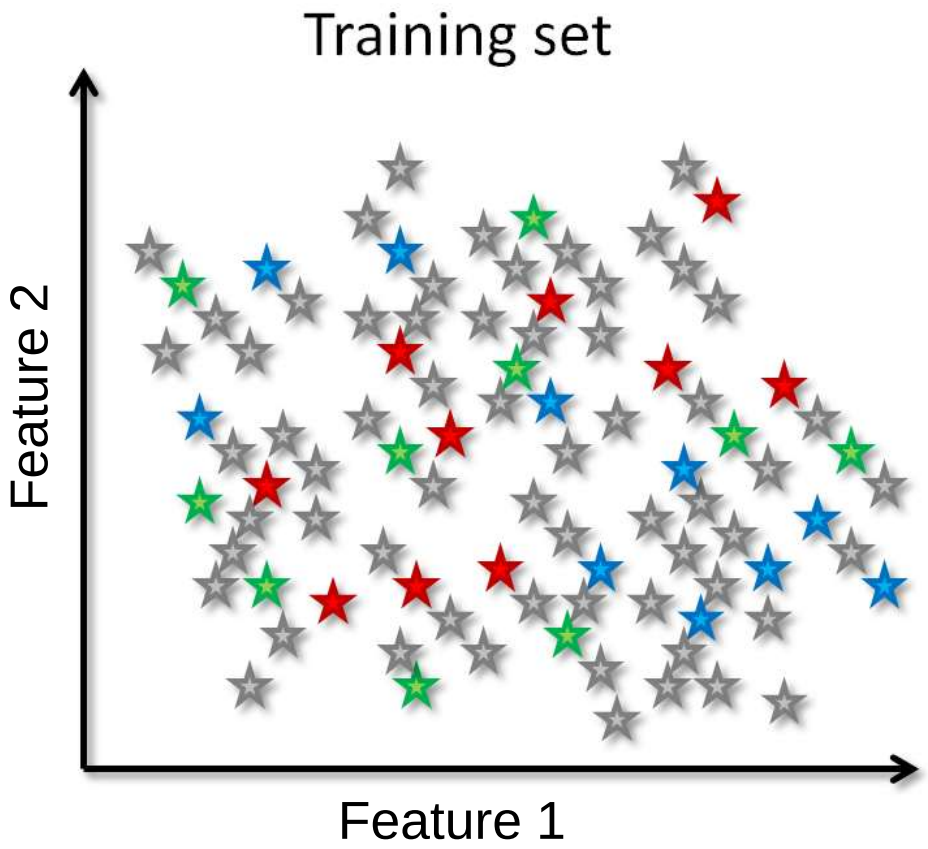
Training Complexity

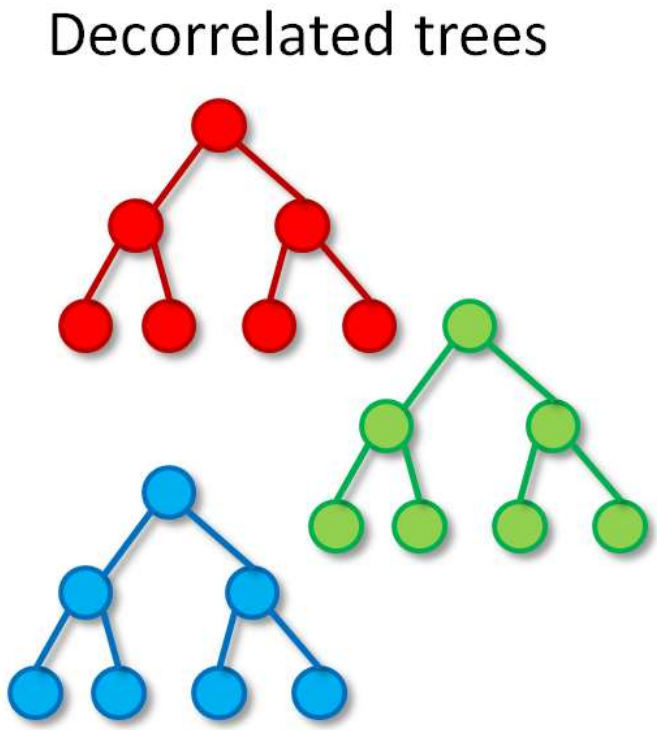


Testing Complexity

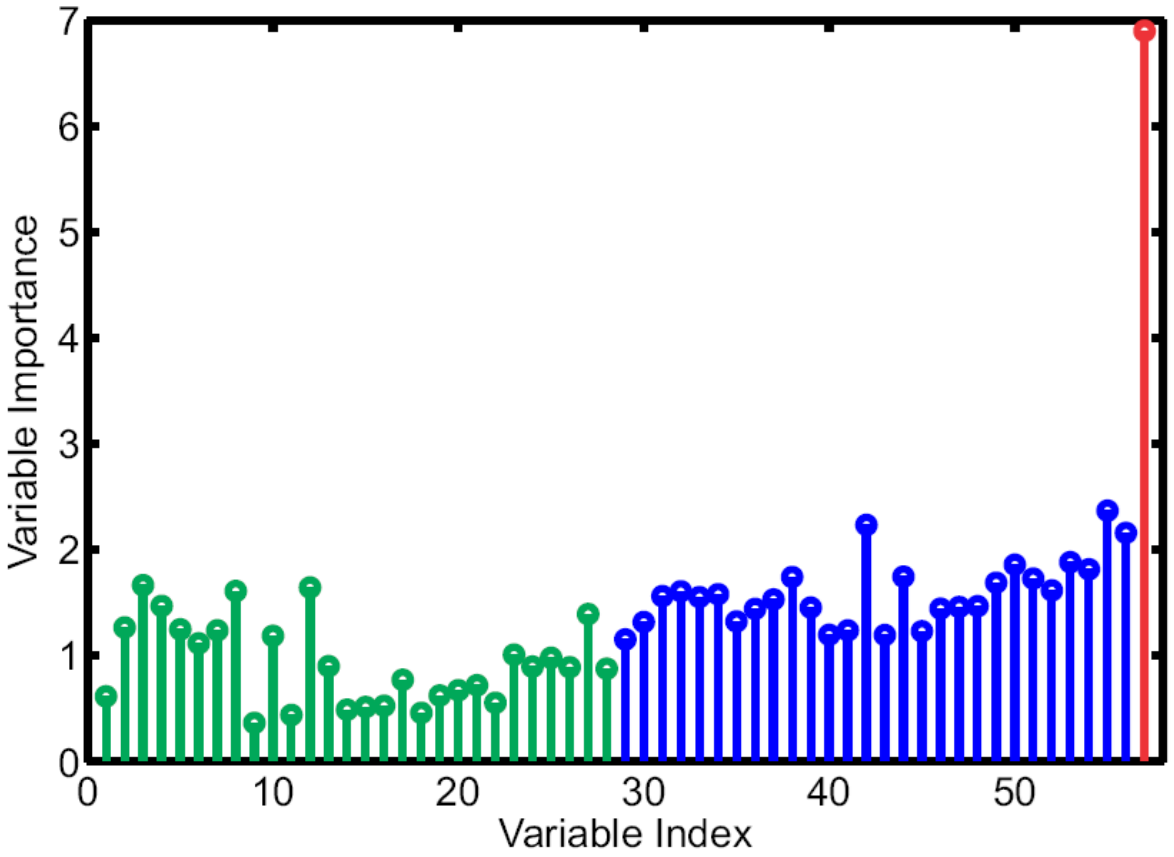


Features and their Role





Variable Importance



Genuer, R., Poggi, J.-M., Tuleau-Malot, C., (2010). Variable selection using random forests. *Pat. Recog. Letters*. **31**(14):2225-2236

WHAT'S HOT IN RESEARCH?

Research Challenges in 2015

- Architecture
  - Online learning
  - Incremental learning
  - Long term memory
  - Parallel - distributed architectures
  - Split functions, cost functions, stopping criteria
  - Domain adaptation
- Engineering and Application
  - Computational complexity
- Statistics and Science
  - Consistency of forests
  - VC dimension
  - De-correlated trees

Take Home Message

- Reading
  - L. Breiman, J. Friedman, C. J. Stone, and R. A. Olshen, *Classification and Regression Trees*. Chapman and Hall/CRC, 1984.
  - L. Breiman, "Random forests," *Machine Learning*, vol. 45, no. 1, pp. 5–32, 2001.
  - A. Criminisi and J. Shotton, *Decision Forests for Computer Vision and Medical Image Analysis*, Springer, 2013.
- Toolboxes and Packages
  - randomForest in R
  - TreeBagger in Matlab
  - sklearn.ensemble.RandomForestClassifier in Python-Scikit-learn
- Conferences
  - Int. Conf. Comp. Vis. (ICCV)
  - Eur. Conf. Comp. Vis. (ECCV)
  - Asian Conf. Comp. Vis. (ACCV)
  - Comp. Vis. Patt. Recog. (CVPR)
  - Med. Image Comp., Comp. Assist. Interv. (MICCAI)