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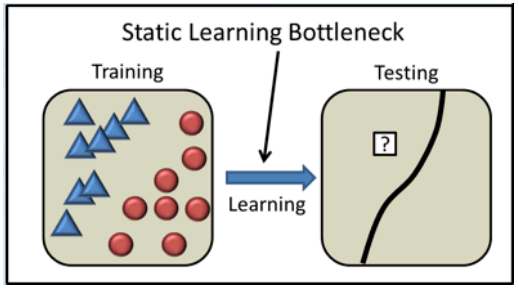
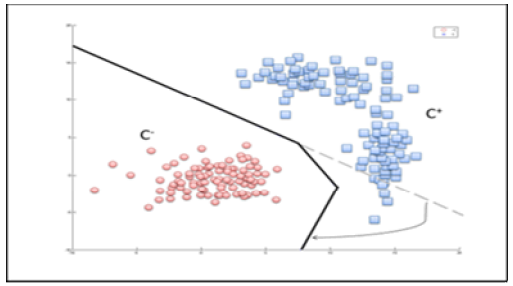




Studying Adaptive Learning through Game-Theoretic Modeling

Craig M. Vineyard

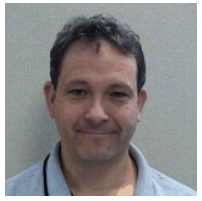
1462—Data Driven and Neural Computing

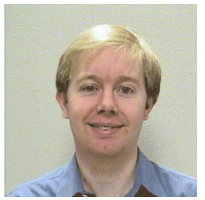
Center for Computing Research

Sandia National Laboratories

Albuquerque, NM

Main Collaborators


Steve Verzi


Brad Aimone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Cindy Phillips

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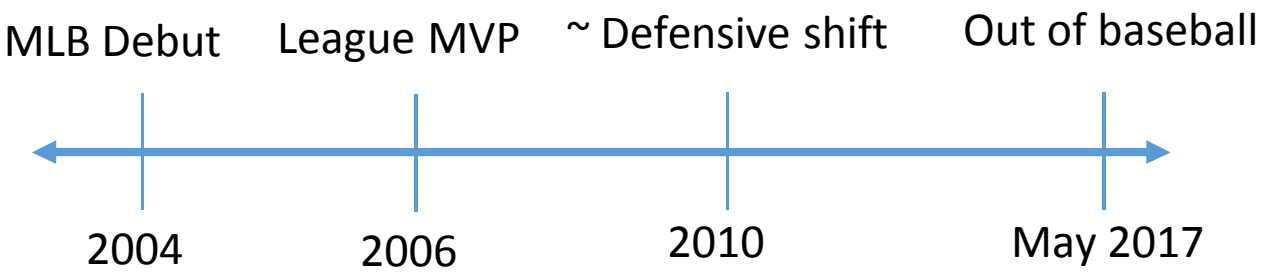
A Tale of Two Sluggers

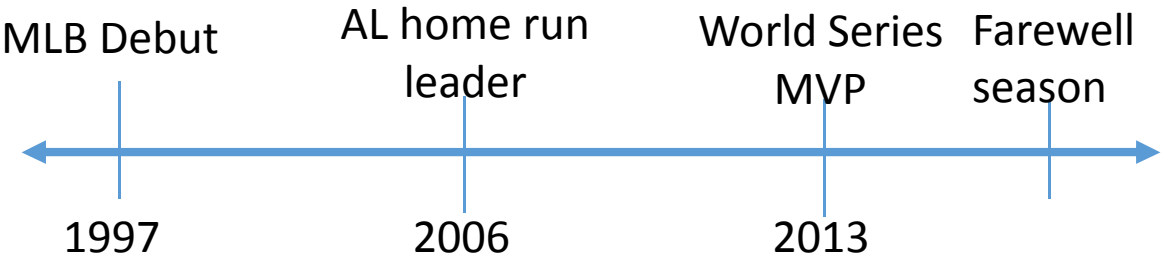
Ryan Howard

- Former Phillies great, fixture in MVP voting, atop league leaderboards
- Defensive Shift – Ended Howard's career



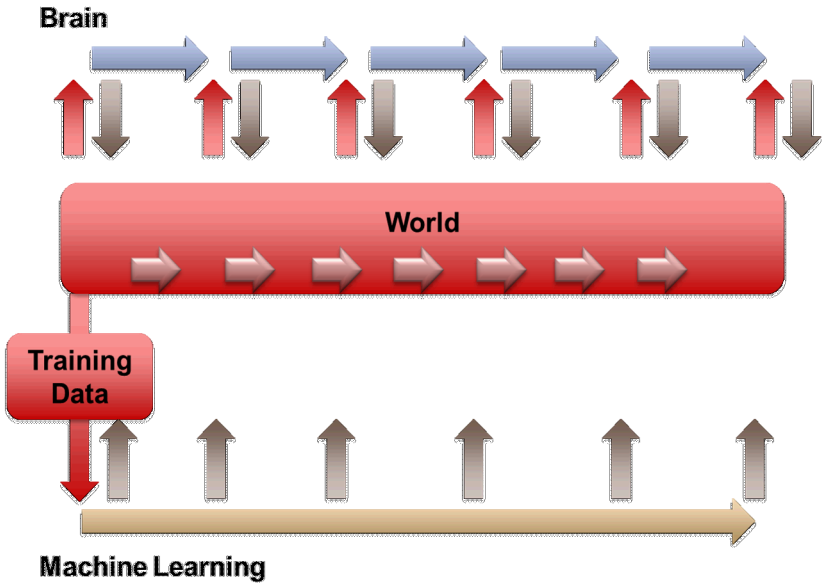
David Ortiz

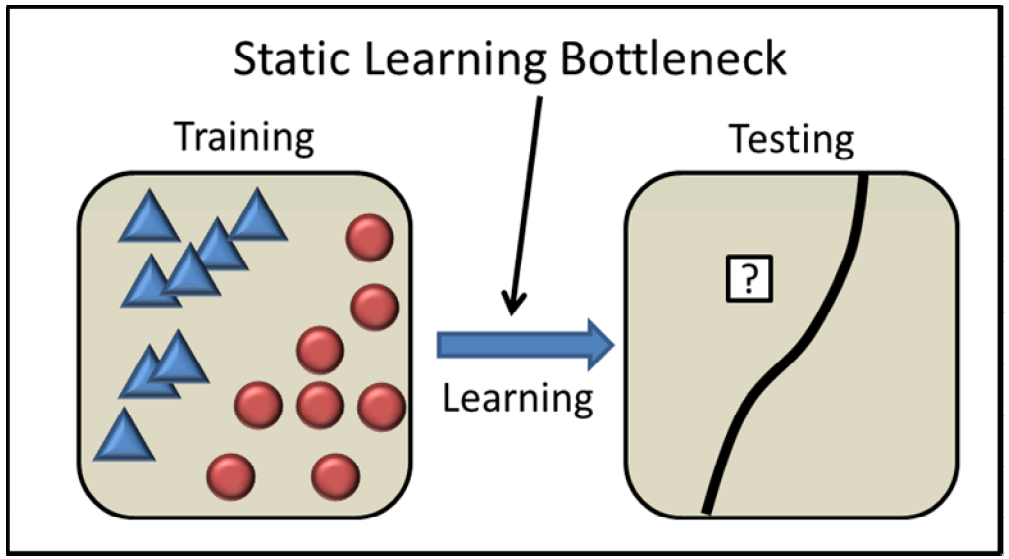
- Former Red Sox great, All-Star, 2013 World Series MVP
- Adapted hitting strategy: hit to opposite field



Adaptive Learning

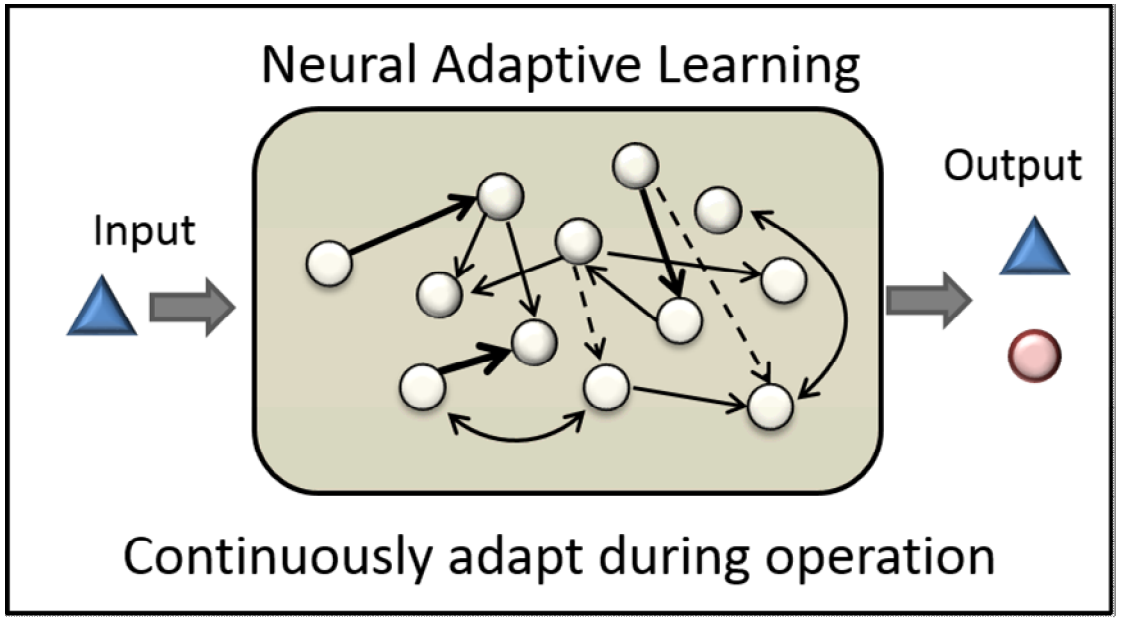
- The learning phase of an algorithm addresses the mechanism by which adjustments are made in the learning process (such as weight tuning in a neural network)





Continuous Neural Adaptation

- Synaptic plasticity
  - Dynamic alteration of the strength of the connections between neurons
- Structural plasticity
  - Addition and eliminations of neural network infrastructure



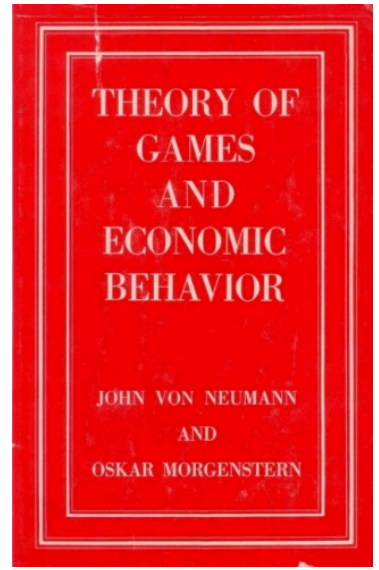
Game Theory

- Game theory is a branch of applied mathematics to formally analyze the strategic interaction between competing players

- When game theory was pioneered by John von Neumann in the early 1940s, the motivating reason was that problems in economics were inadequately formulated with standard methods from optimization theory.
  - Real world economic problems involving dynamic interactions were not adequately captured by single global objective functions and therefore needed a different approach

- An analogous statement can be said about machine learning

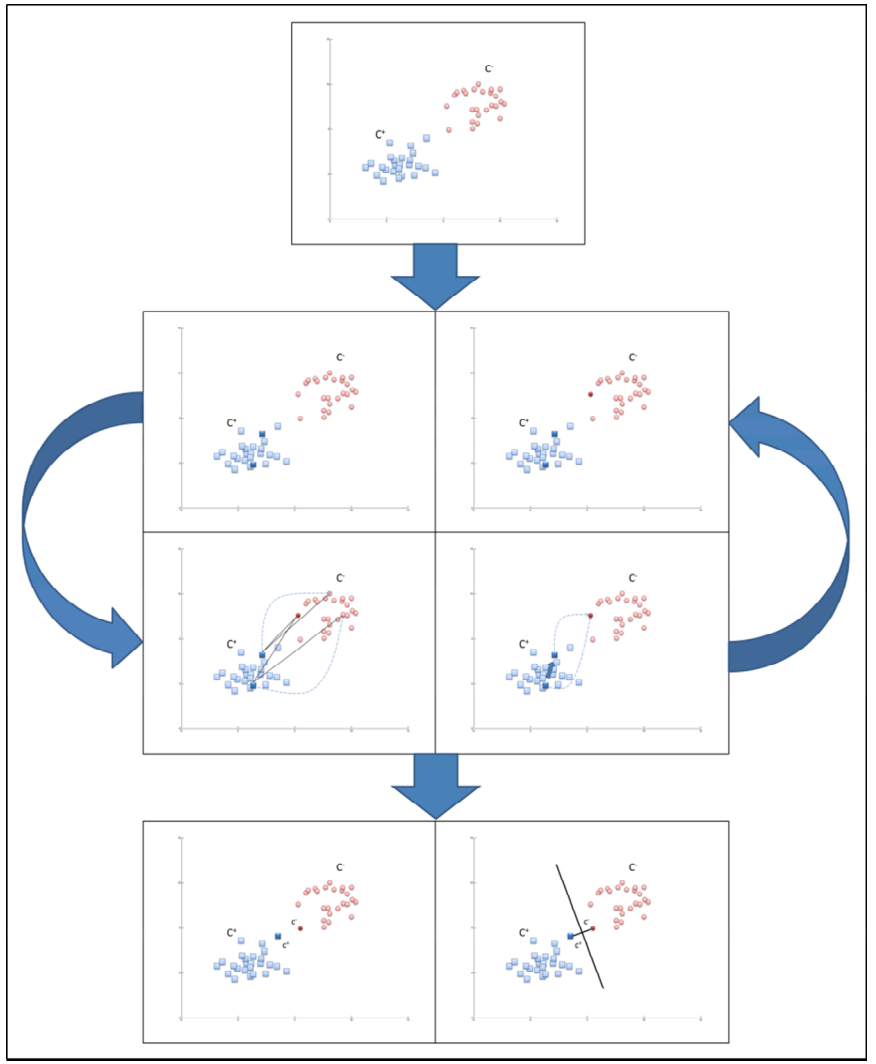
- Applying Game Theory to Learning
  - SVM Game
  - FLANEL



SVM Game

- Two player iterated game
  - Data patterns are the players
- Each iteration of the game:
  - Randomly select two players from the same class and one data pattern from the opposing class
  - Each player has two possible actions, to pass (transferring some of its α to the other player), or to hold (keeping its own α)
  - A player must pass when it is further than its opponent from the other class data pattern

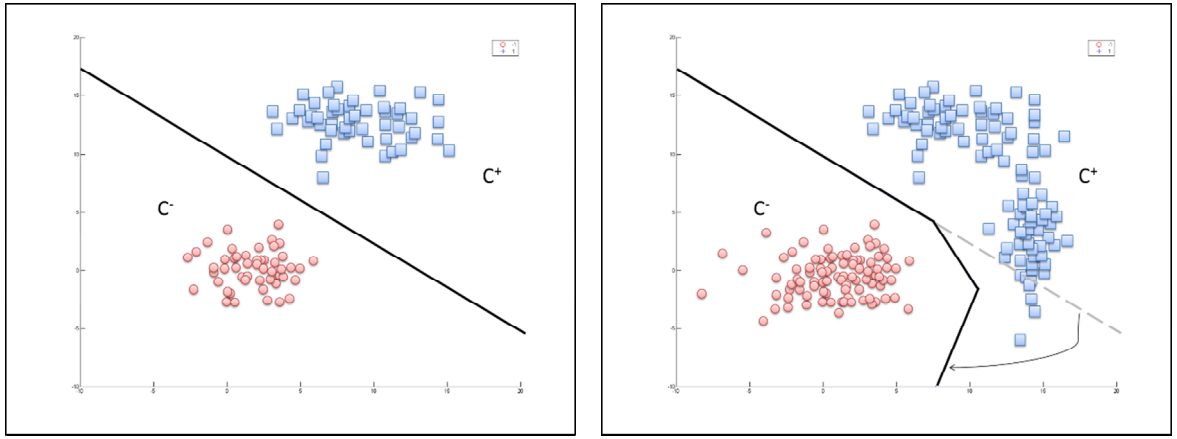
SVM Game Algorithm Illustrated



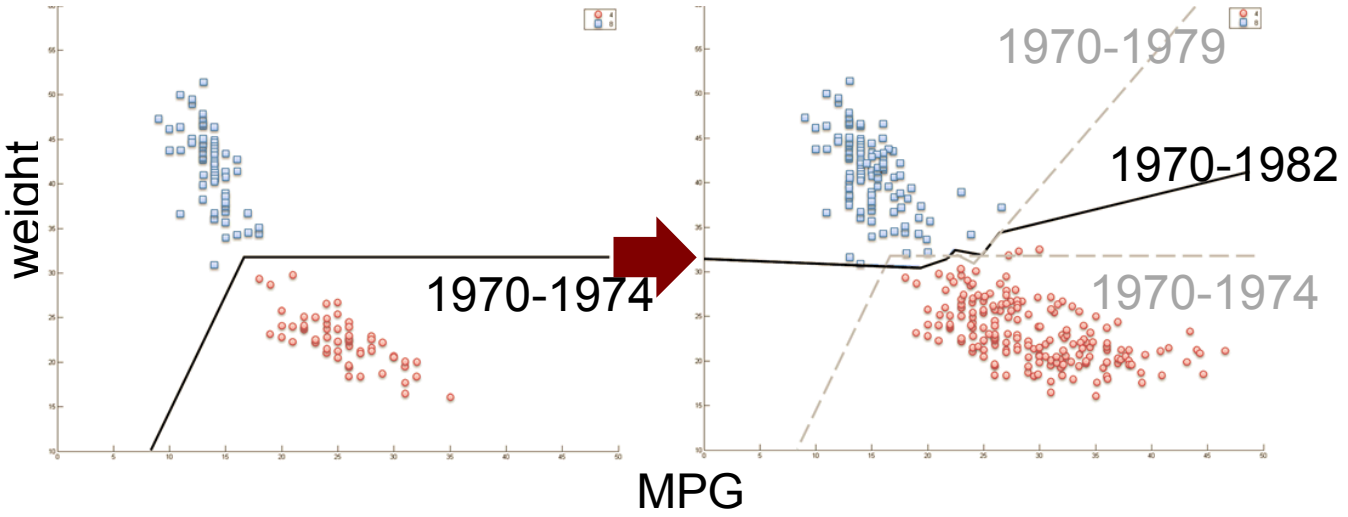
Vineyard et al, IJCNN 2015

SVM Game Examples

- Repeated SVM Game

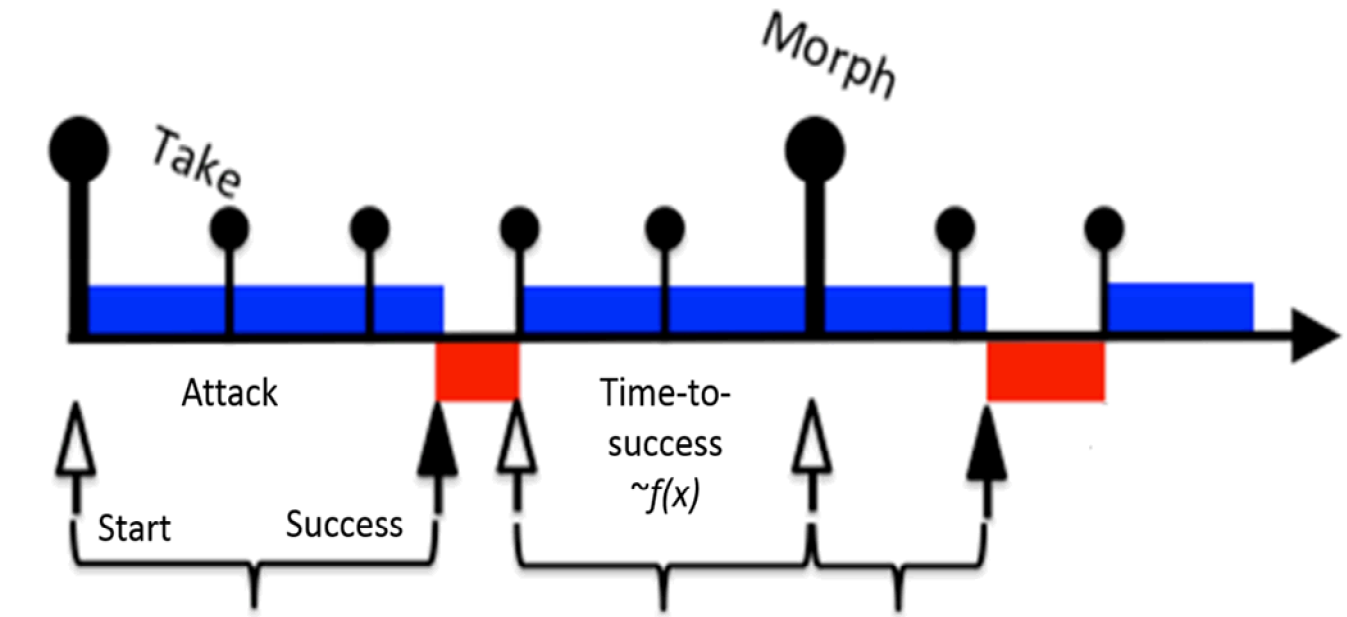


- Automotive Example



PLADD

- Probabilistic Learning Attacker Dynamic Defender (PLADD)
  - Extension of FlipIt attacker and defender model
- Two players & one contested resource
- A player can move at a cost
  - The “take” move - seizes control of the resource immediately
  - The “morph” move - resets the game
- Neither player ever knows who owns the resource
- Strategy: when to move?

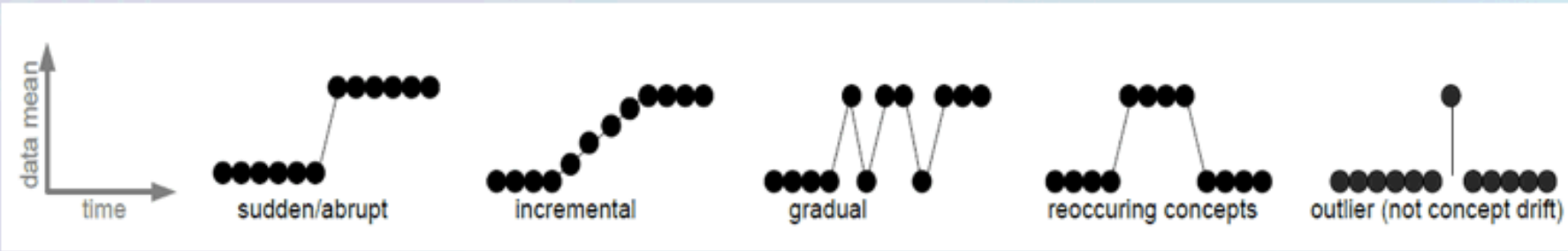


PLADD for Learning = FLANEL

- Fundamental Learning Algorithm aNalysis and Exploration of Limits (FLANEL)
  - Modest extension that adds considerable complexity

Lots of Way the World Can Change

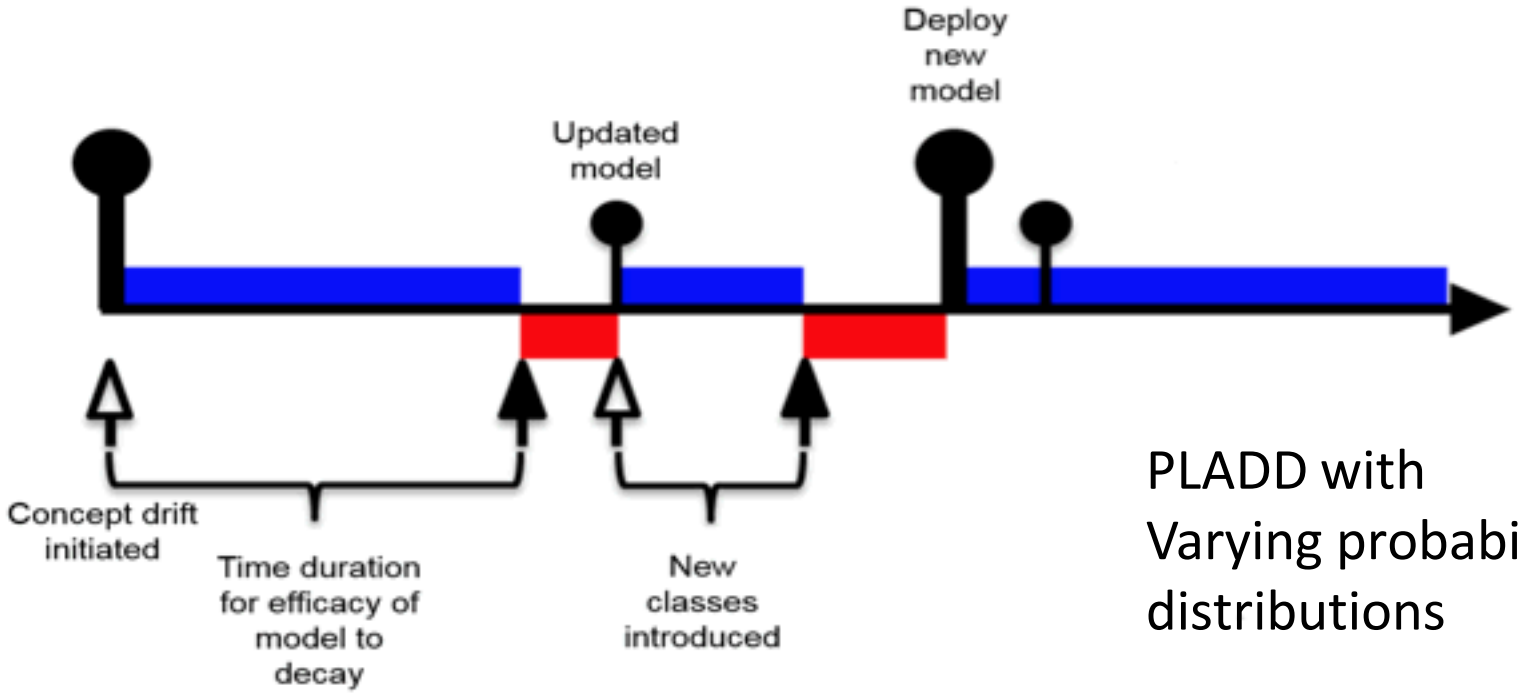
➢ Sample data change patterns over time



Gama, João, et al. "A survey on concept drift adaptation." *ACM Computing Surveys (CSUR)* 46.4 (2014): 44.

FLANEL

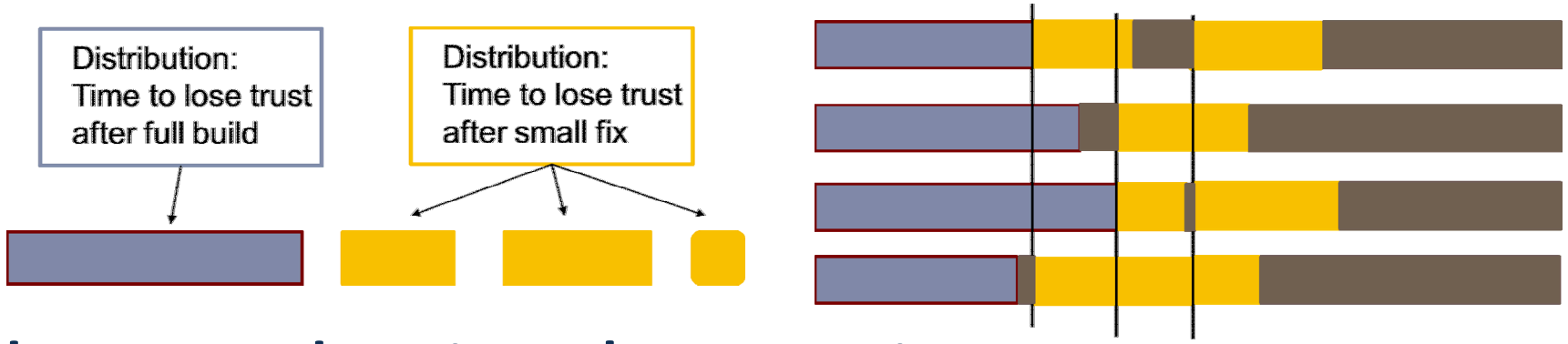
- Morph = Rebuild the system (e.g. classifier)
- Take = Short-term improvement



PLADD with Varying probability distributions

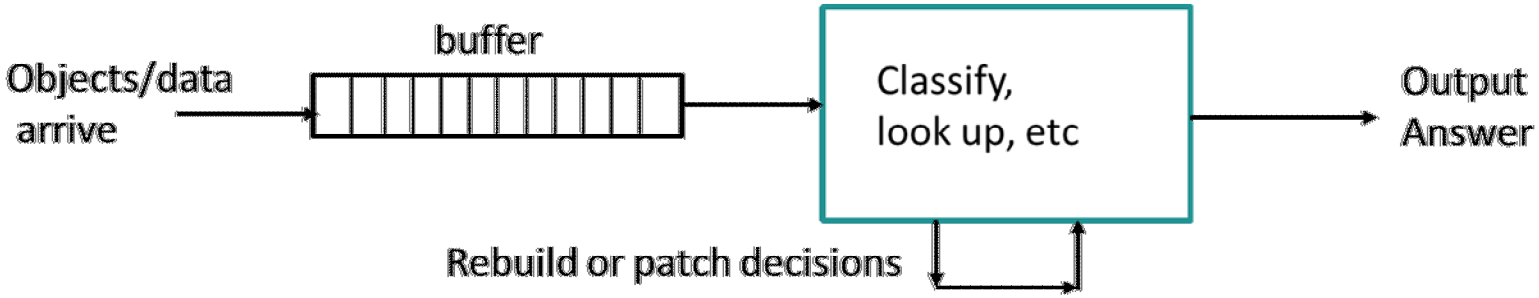
Method 1: Stochastic Programming

- Key idea: approximate uncertainty by sampling outcomes
- Optimize to determine the defender's single best strategy against ALL scenarios



Method 2: Study Simpler Settings

- Algorithm decides when to rebuild or patch based on performance and budget



Conclusion

- Static Learning Bottleneck – need for adaptive learning
- Working on a theoretical understanding of the problem
  - Need a holistic view not just Band-Aid solutions for individual problems
  - Mathematics of game theory are advantageous
    - SVM Game as an adaptive game-theoretic adaptive algorithm
- Presented FLANEL as an adaptive learning analysis framework
  - Intended to provide a foundation for quantitatively evaluating adaptation in learning systems
  - Potential to impact how ML algorithms are implemented and deployed
  - Such insights can be impactful for: V&V, Autonomy, Neuromorphic hardware/architectures

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Thank you