Improving the Performance of a RoboCup Case-Based Imitation Agent through Preprocessing of the Case Base

Michael Floyd

Thesis Defense
December 1, 2008

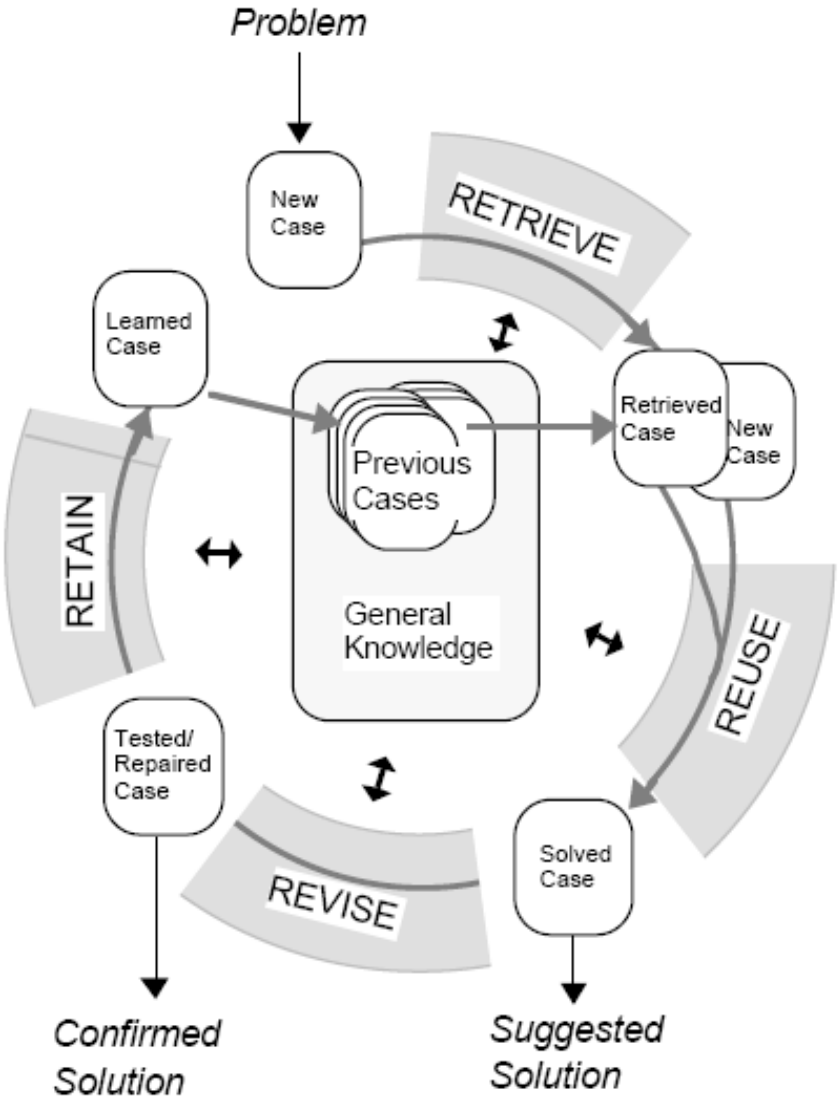
Overview

- Motivation and Background Information
- Objectives and Contributions
- Literature Review
- Methodology
- Experimentation and Results
- Conclusions and Future Work

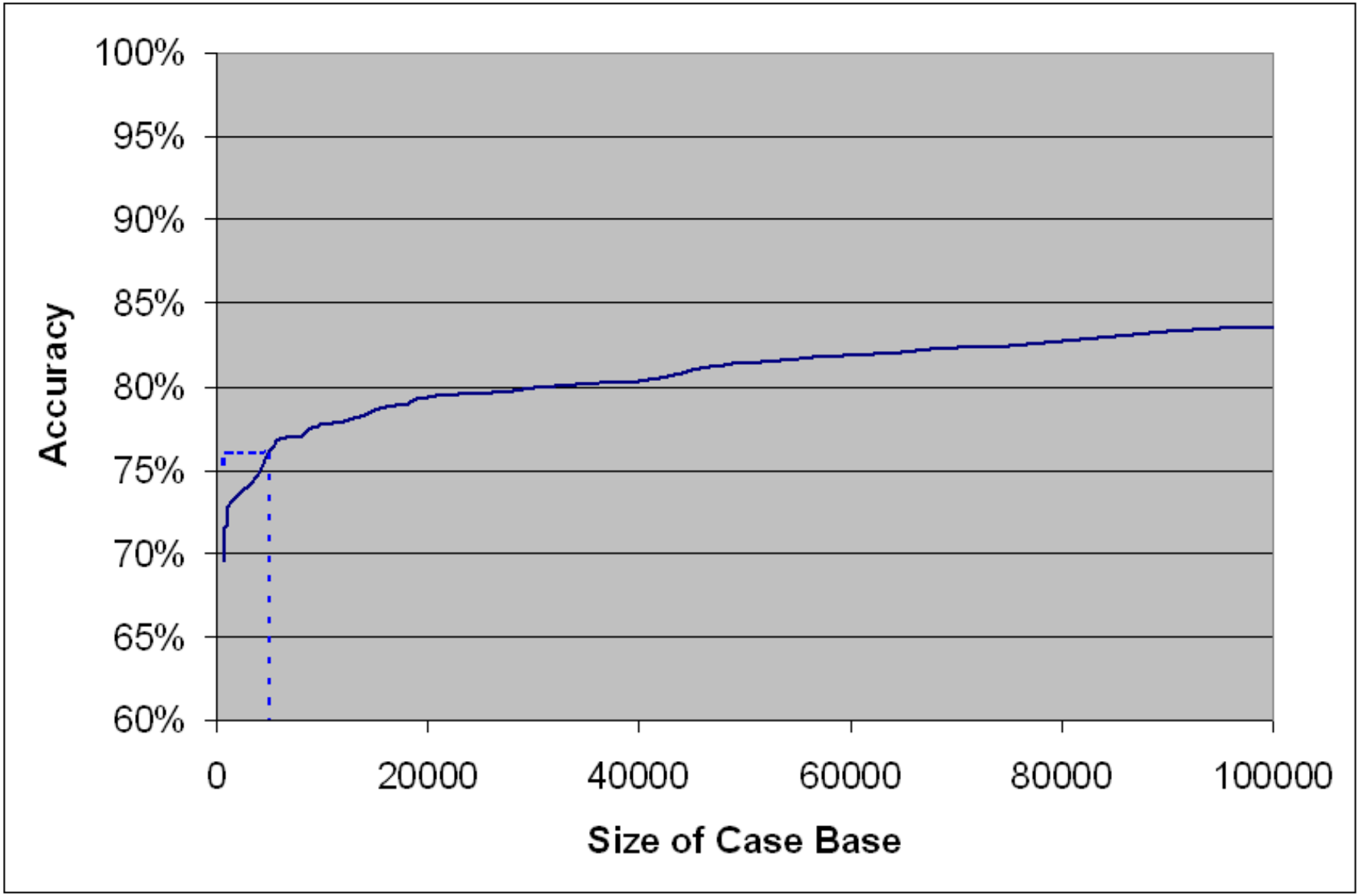
Motivation

- Transferring knowledge from domain expert to agent can be tedious
- Automate the process by learning from observation - remember input-action pairs
- Agents often operate in real-time, can only search so many pairs
- How do we choose which pairs to use?

Case-Based Reasoning

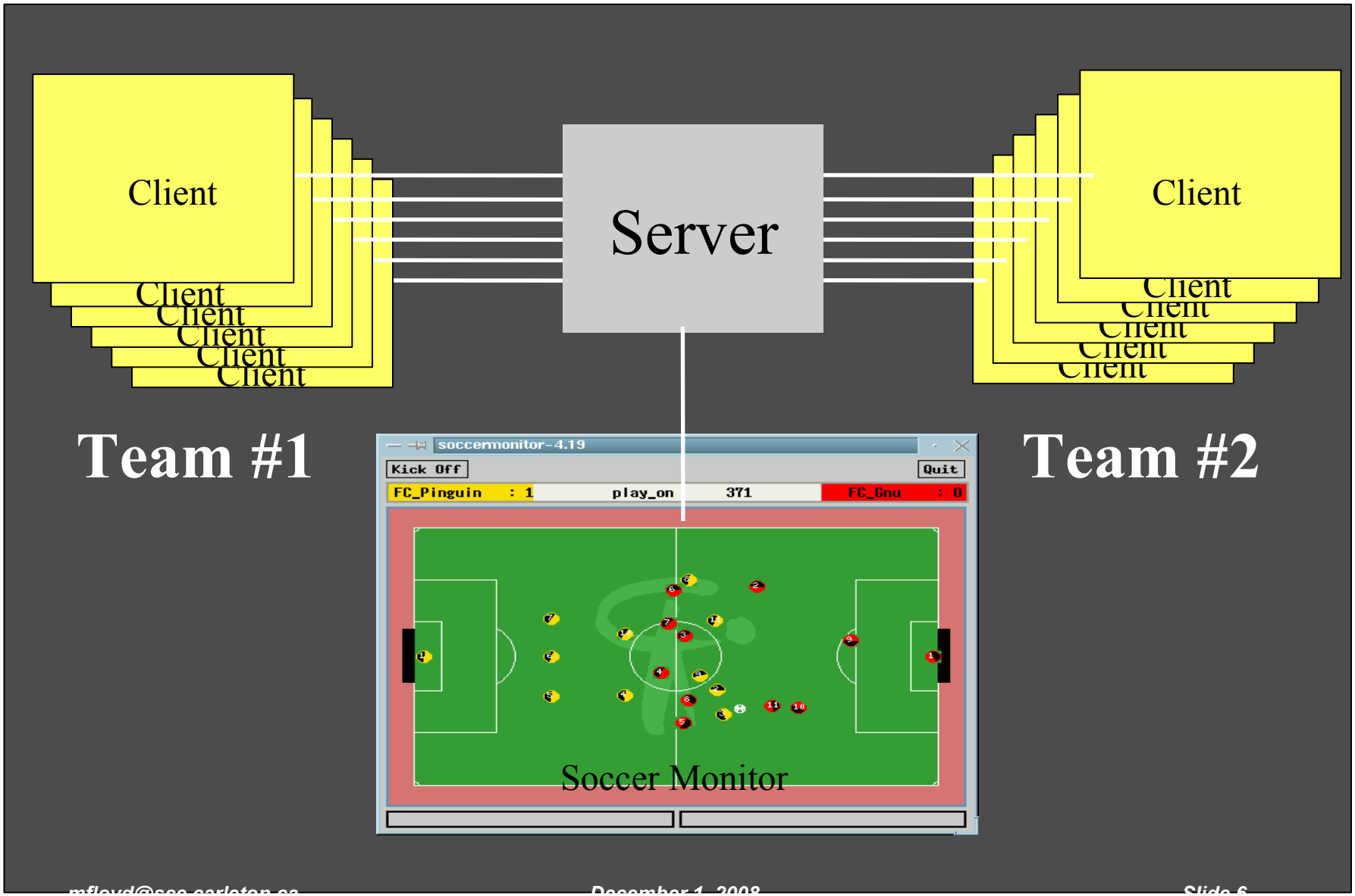


Source: Aamodt and Plaza, "Case-based reasoning: foundational issues, methodological variations, and system approaches", 1994

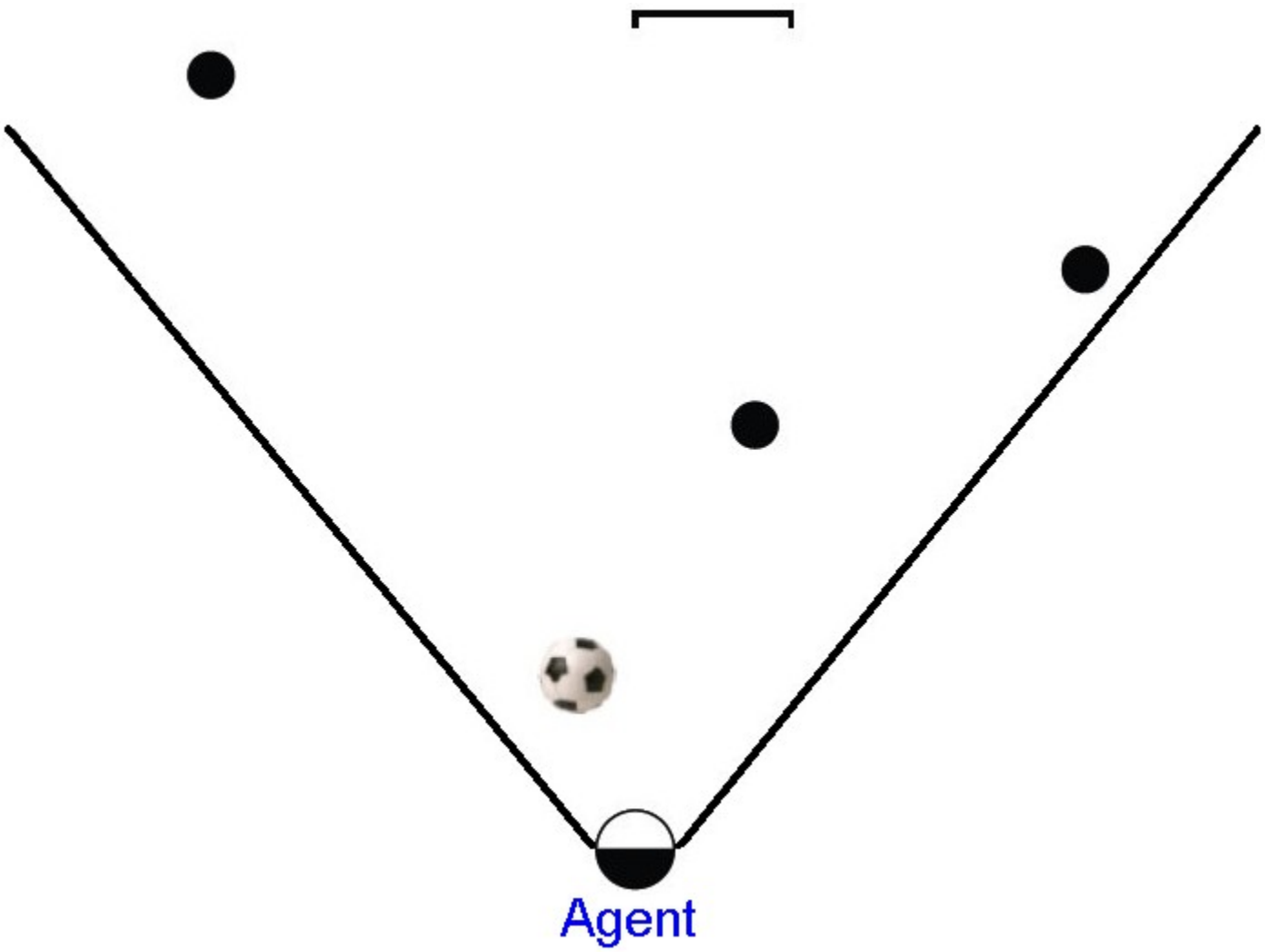


* Data obtained from the Krislet agent

RoboCup


Client
Client
Client
Client
Client
Client
Server
Client
Client
Client
Client
Client
Team #1
Team #2
soccermonitor-4.19
Kick Off
Quit
FC_Pinguin : 1
play_on
371
FC_Gnu : 0
Soccer Monitor

Agent Inputs and Output



Actions:

- Dash
- Turn
- Kick
- Catch

Objectives

Research Question: *In the domain of simulated RoboCup soccer, how can the imitative ability of a real-time case-based imitation agent improve by preprocessing the case base it uses?*

Objectives (2)

Feature Removal: *Will removing less relevant features from cases result in a decrease in execution time, and by how much, without negatively affecting the imitative performance of a RoboCup imitation agent?*

Case Prototyping: *Can sets of similar cases, grouped using data clustering, be replaced with a single prototypical case without a significant negative effect on the performance of a RoboCup imitation agent? What level of compression can be achieved before negative performance occurs?*

Combined: *Does combining feature removal (1) and prototyping (2) result in improved performance compared to using each technique separately, and does the order of preprocessing matter?*

Contributions

Evaluation: various feature selection, clustering and prototyping methods using RoboCup imitation data

- **Feature Selection:** A binary feature selection algorithm with a dynamic-sized training set
- **Clustering:** Transforming the data using the distance vector approach and then using k-means clustering
- **Prototyping:** Creating an average case
- **Hybrid:** Performing feature reduction before prototyping

Contributions (2)

Development:

- A method of feature selection, that can be used with existing algorithms, that considers the cost of retaining features when selecting an optimal feature set.

- Variants of existing prototyping methods for RoboCup imitation data

- Open-source agent imitation framework using CBR

Literature Review

Robot and Agent Imitation

- Does well imitating single tasks, but trouble with a set
- Significant expert knowledge

Real-time CBR

- In RoboCup, expert knowledge and complete world view
- In other domains, do not deal with real-time limits

Case Base Maintenance

- Knowledge level - addition and removal of cases based on coverage/adaptability
- Implementation level – indexing the case base in some way

Methodology

- Test preprocessing algorithms on RoboCup data
- Use algorithms to ensure real-time constrains are met

Data Source

Five Teams:

- Sprinter – runs from goal to goal
- Tracker – runs after the ball
- Krislet – runs after ball and kick to opponents goal
- NoSwarm – does not go to ball if teammate closer
- CMUnited – complex, previous world champion

Performance Metrics

Imitative performance:

- *Precision*
- *Recall*
- *Accuracy*
- *F1-measure* – function of precision and recall

Clustering:

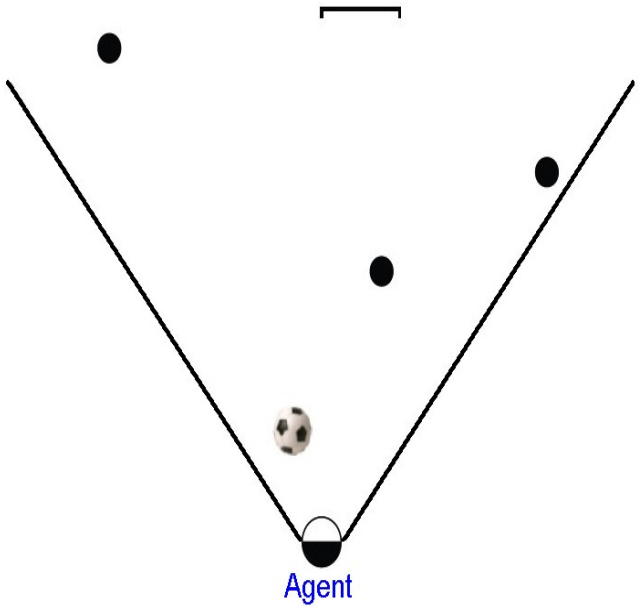
- *Consistency* – purity and entropy
- *Compactness and separation* – Davies-Bouldin and Dunn index

Feature Removal

$$\text{Distance}(\text{case1}, \text{case2}) = f(x_1, \ldots, x_n)$$

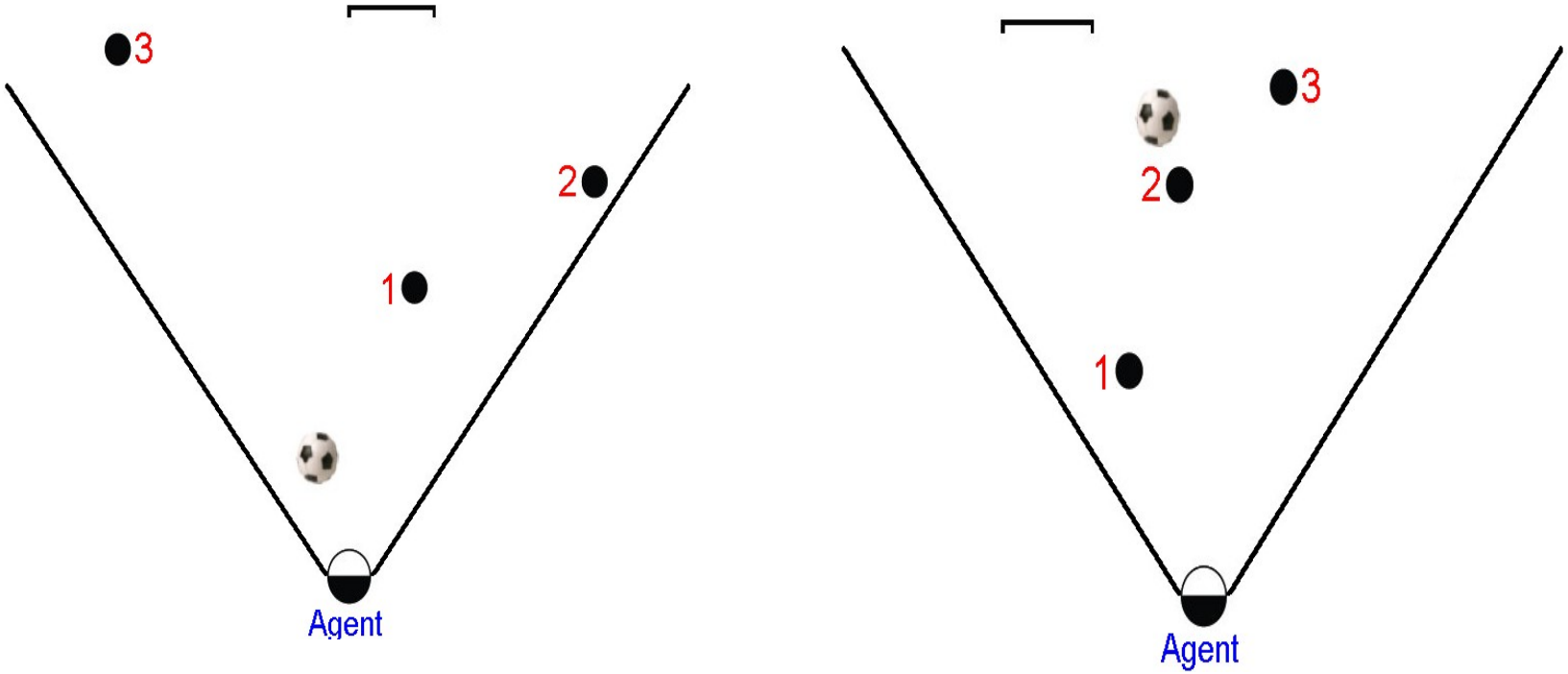
Multi-valued features due to noise:

- Ball
- Goal net
- Lines
- Flags
- Teammates
- Opponents
- Unknown players



Distance Calculation

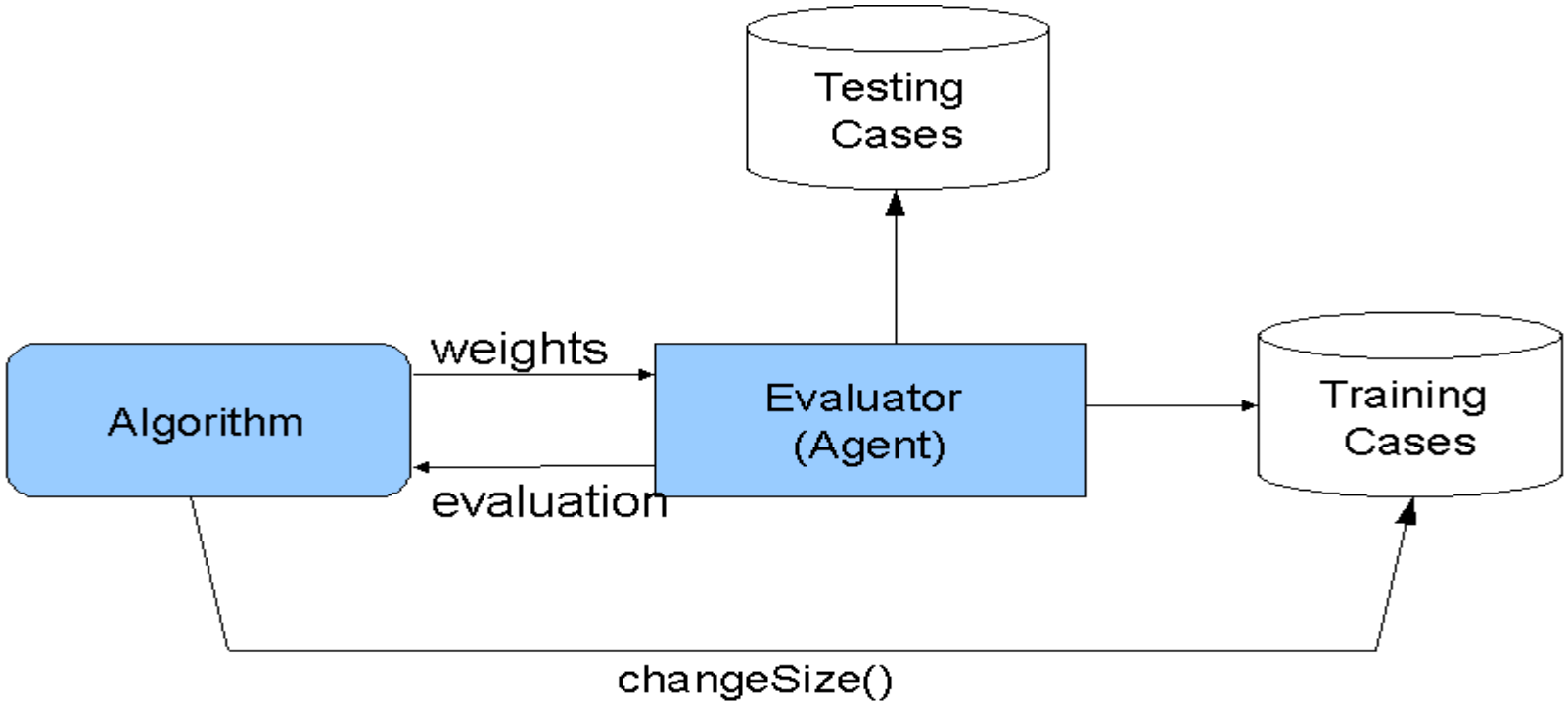
- Matching required so feature distances can be calculated



- Feature distances are then weighted and summed

Feature Selection Algorithms

- *Binary weighting* - either included or excluded
- *Continuous weighting* – any value between 0 and 1
- Using both a fixed size and dynamically sized training set



Dynamically-sized Training Set

- Estimates real-time case limit based on number of non-zero feature weights

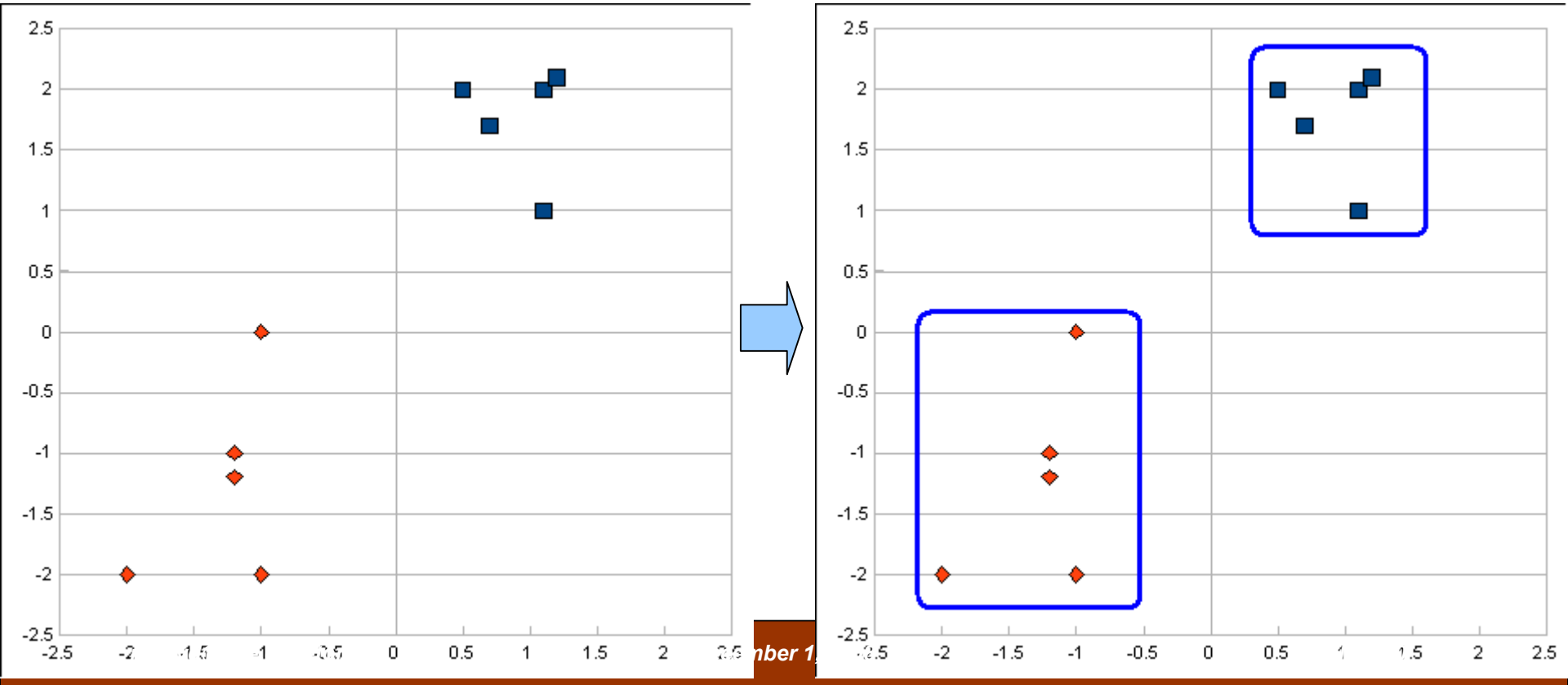
- Uses that sized training set, rather than a fixed size

Features	Max. Cases
3/3 included	N
2/3 included	1.5N
1/3 included	3N

Clustering and Prototyping

Group similar cases:

- Leader algorithm
- Single-linkage algorithm
- Distance vector with k-means



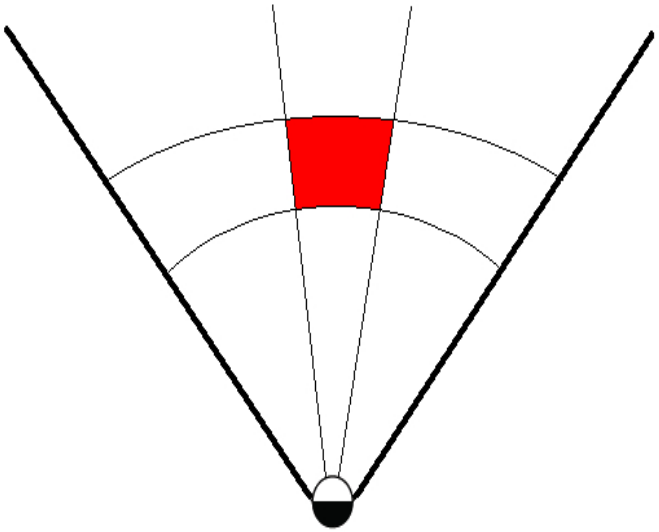
Prototyping

Replace a cluster of cases with a single case

Cluster Member: Clust = $\{C_1, ..., C_n\}$ ==> P $\in$ Clust

Cluster Average: average of each feature value (position)

Cluster Range: each feature can be a range of values

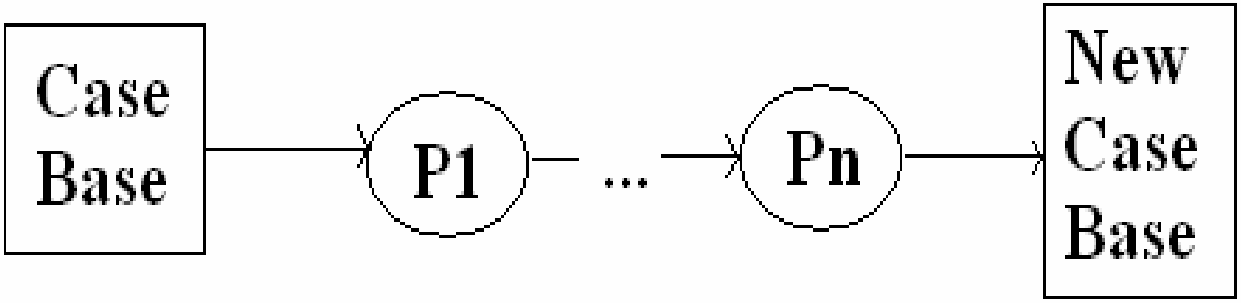


Hybrid

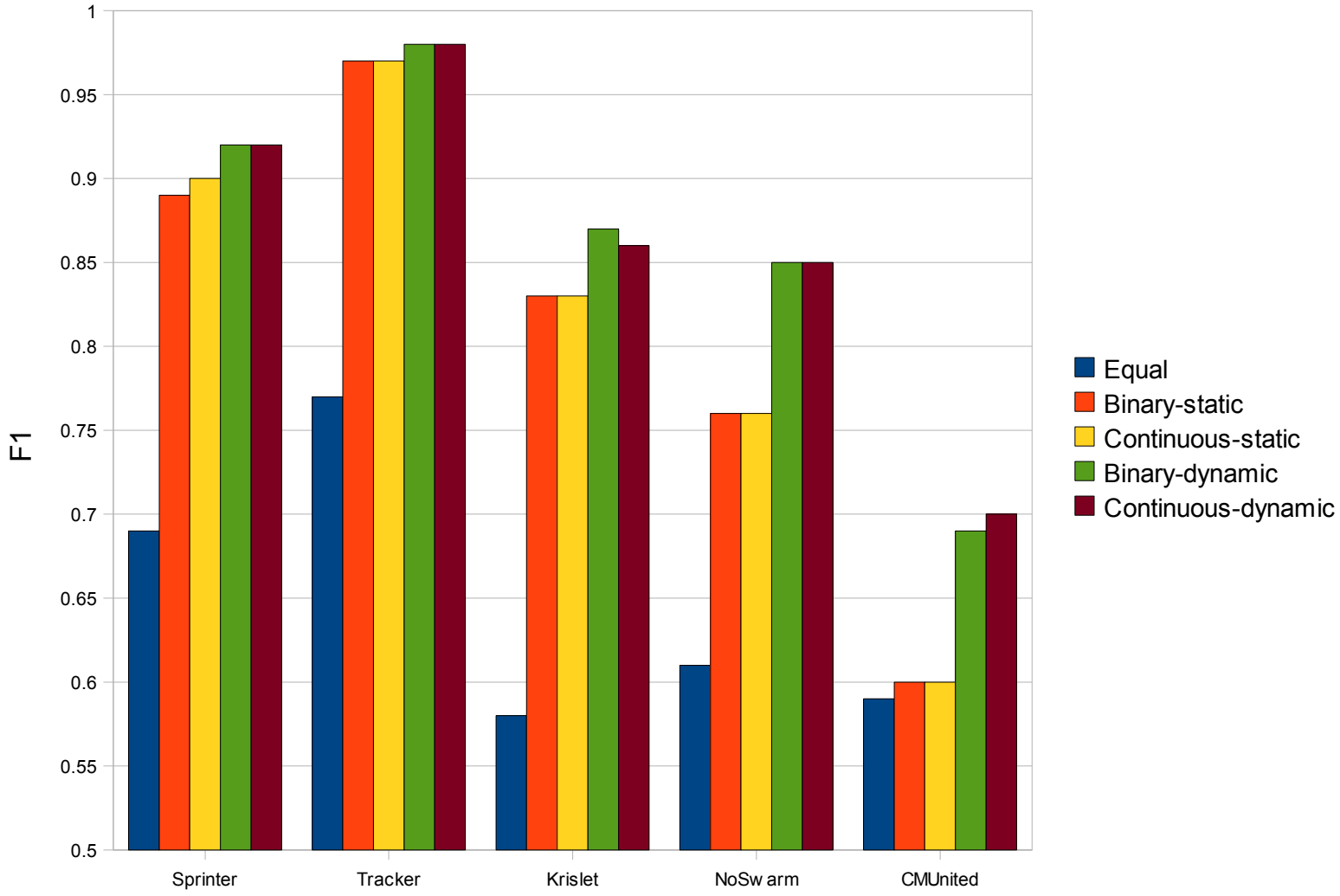
Order of prototyping:

- Feature reduction before prototyping
  - reduce dimensions

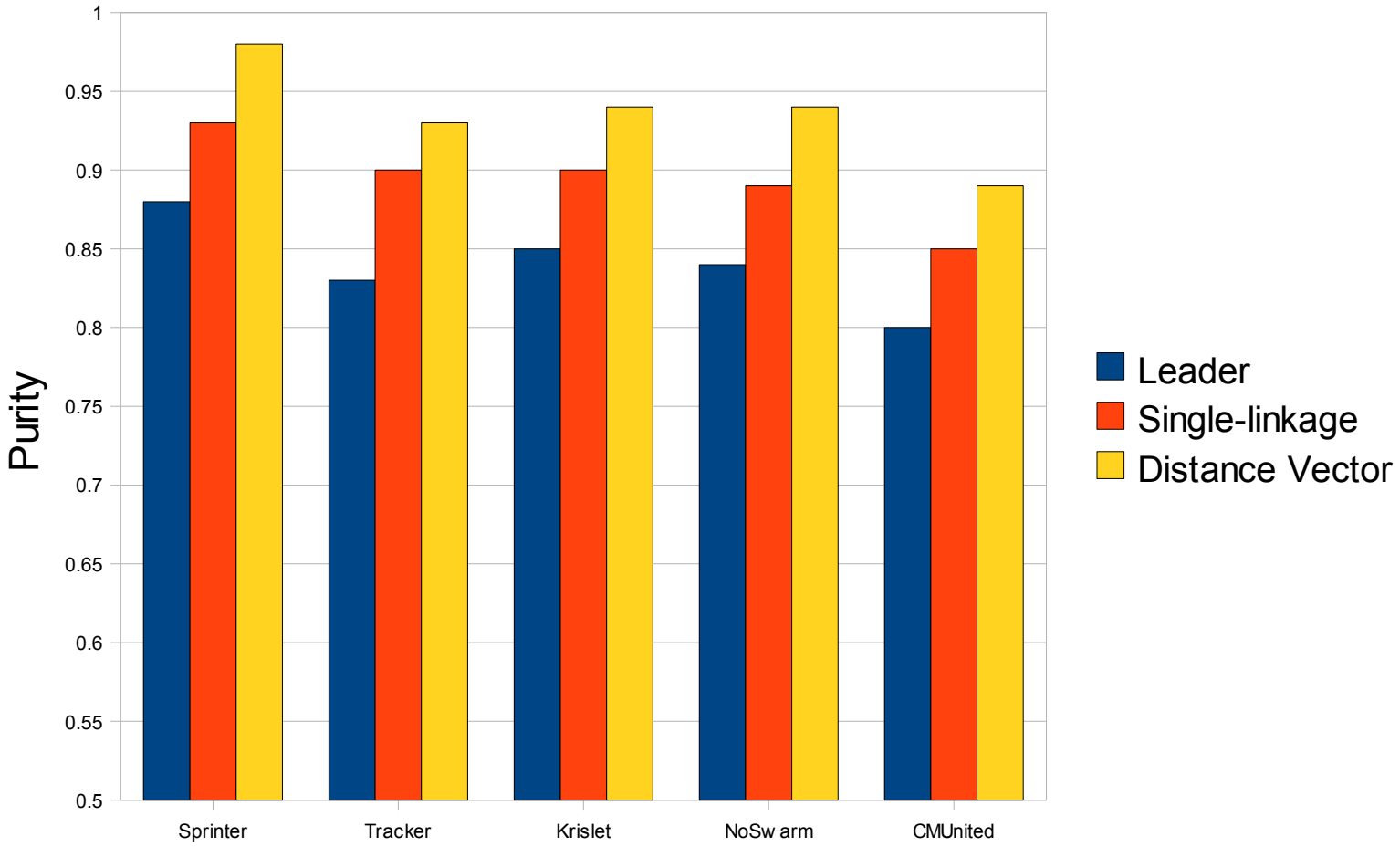
- Prototyping before feature reduction
  - avoid using redundant information in training set



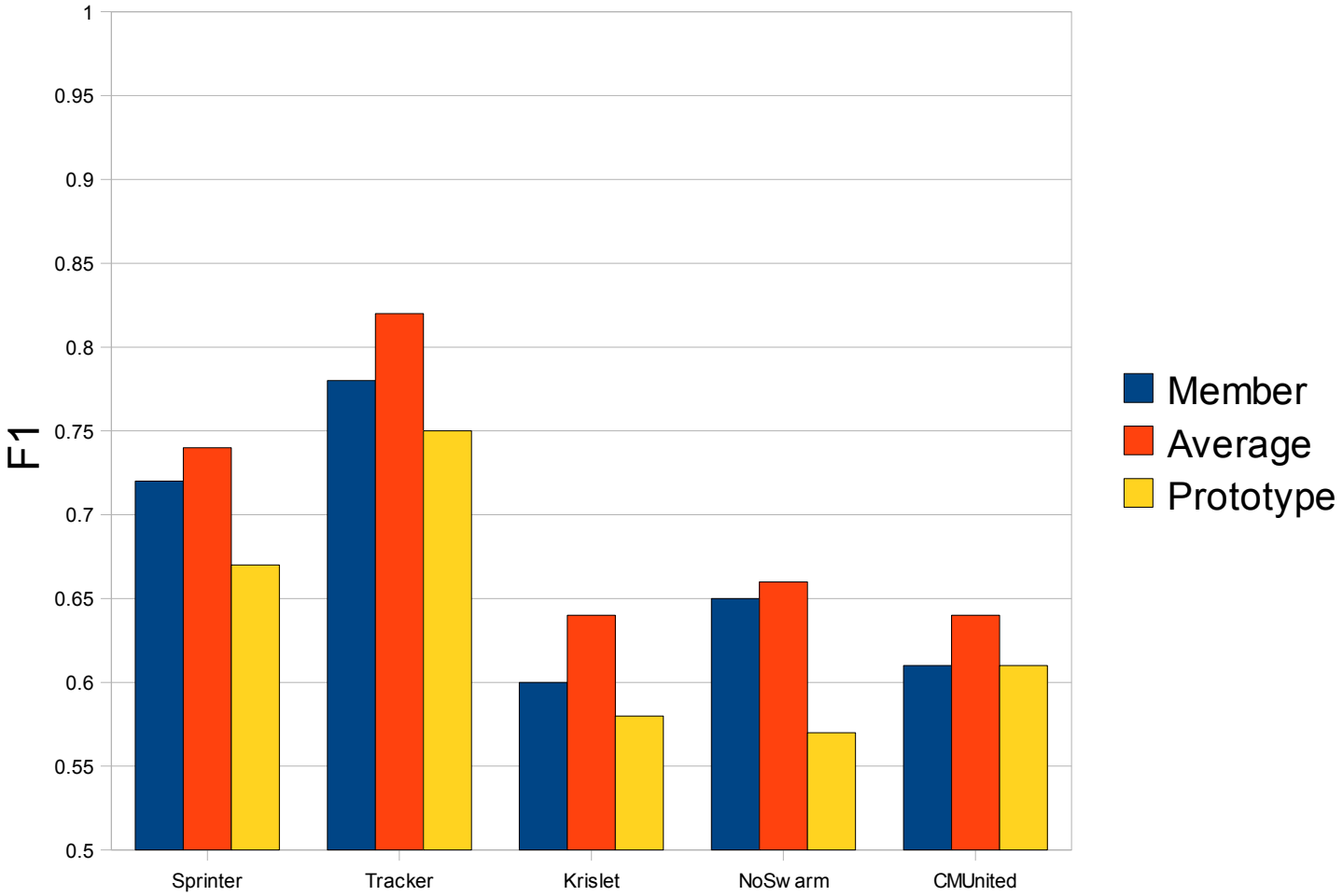
Key Results – Feature Reduction



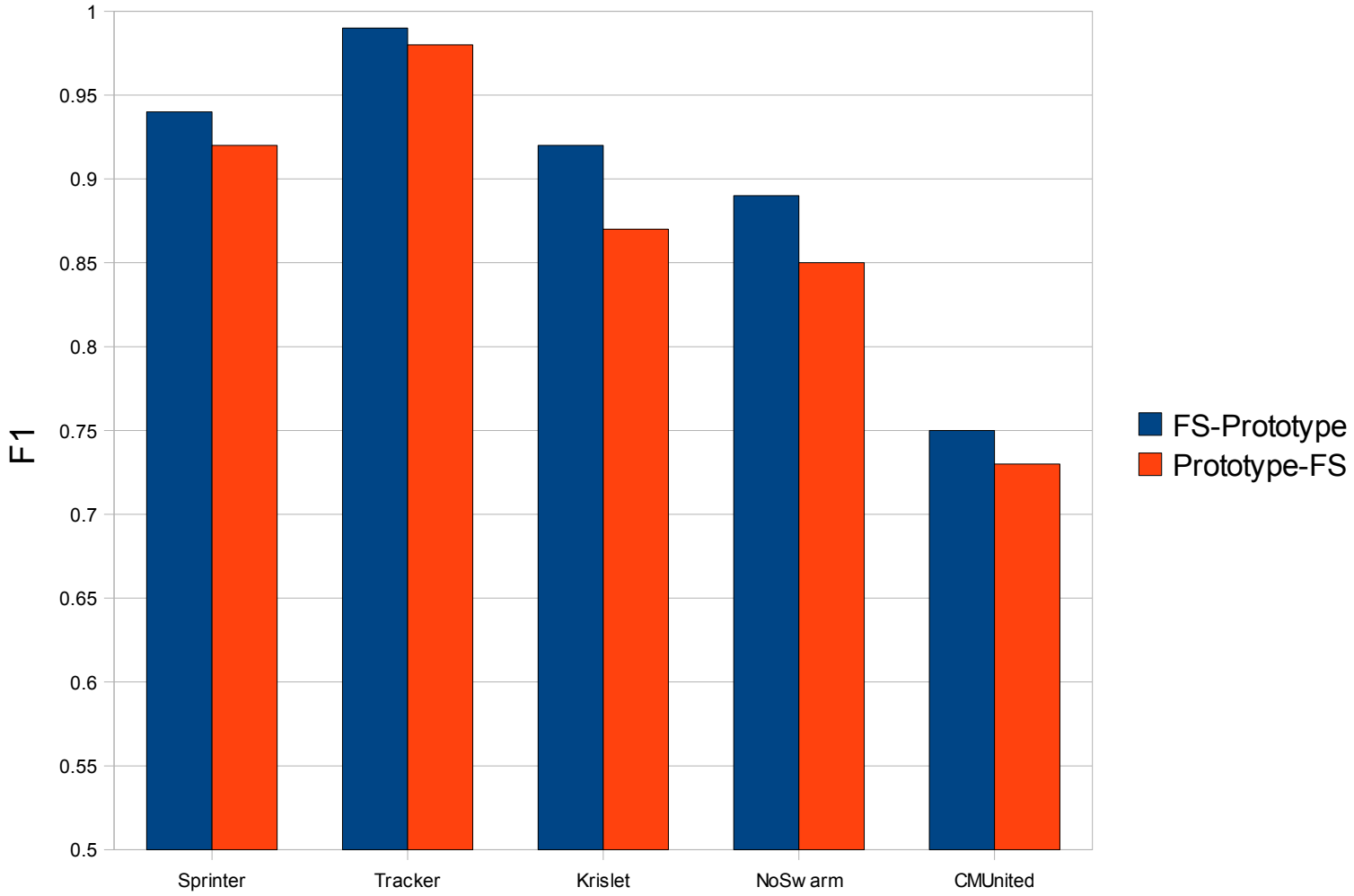
Key Results - Clustering



Key Results - Prototyping



Key Results - Hybrid



Demo

Conclusions

- Preprocessing significantly improves performance
- Most beneficial for complex teams
- A set of suitable algorithms found for each preprocessing type

Future Work

- Improve ability to imitate complex teams (non-reactive agents)
  - Non-visual inputs
  - Past visual inputs
- Deploy in other domains
- Guide the case acquisition process

Derived Works

a) M. W. Floyd, A. Davoust, and B. Esfandiari. Considerations for real-time spatially aware case-based reasoning: A case study in robotic soccer imitation. In Proceedings of the European Conference on Case-Based Reasoning (ECCBR), pages 195-209, 2008.

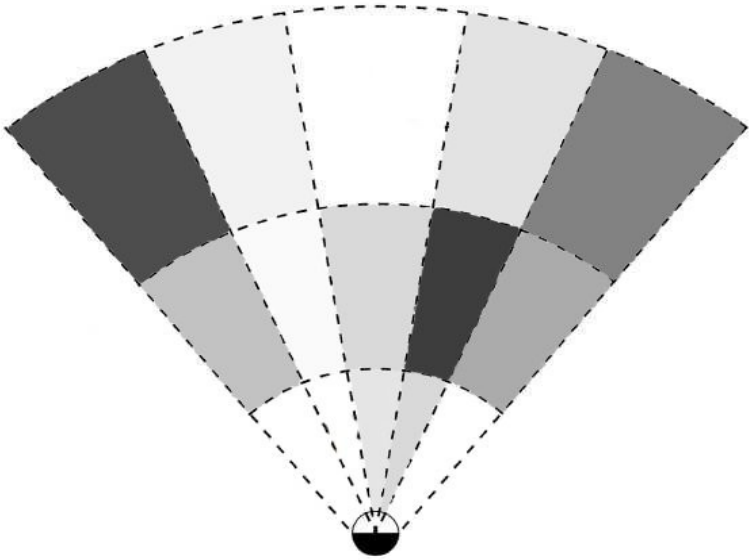
b) M. W. Floyd, B. Esfandiari, and K. Lam. A case-based reasoning approach to imitating RoboCup players. In Proceedings of the Florida Artificial Intelligence Research Society Conference (FLAIRS), pages 251-256, 2008.

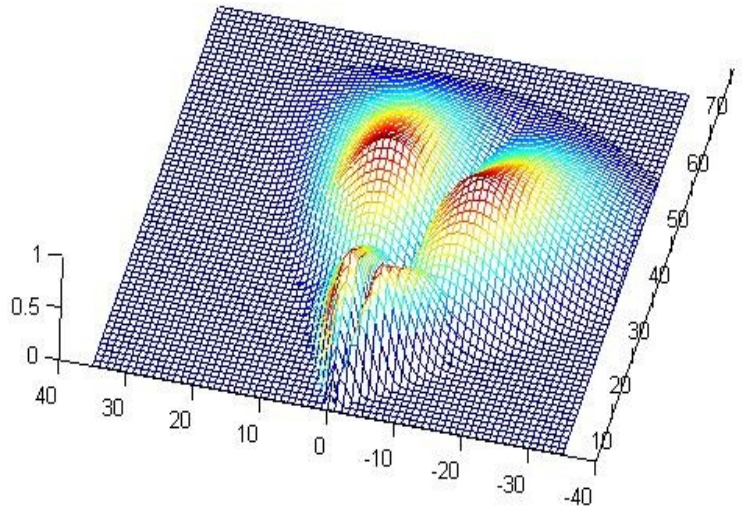
c) A. Davoust, M. W. Floyd, and B. Esfandiari. Use of fuzzy histograms to model the spatial distribution of objects in case-based reasoning. In Proceedings of the Canadian Conference on AI, pages 72-83, 2008.

d) Best Educational Video, Artificial Intelligence Video Competition at the Association for the Advancement of Artificial Intelligence Conference 2008 (AAAI08).

http://www.nmai.ca

Histogram Approach





- Discretization of the region
- Each object gives membership to cell it is in
- Can be visualized by a 3D histogram
- Does not perform as well for kick action