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# VORAI: A MULTI-OBJECTIVE VORONOI DIAGRAM-BASED ARTIFICIAL IMMUNE SYSTEM

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## Context

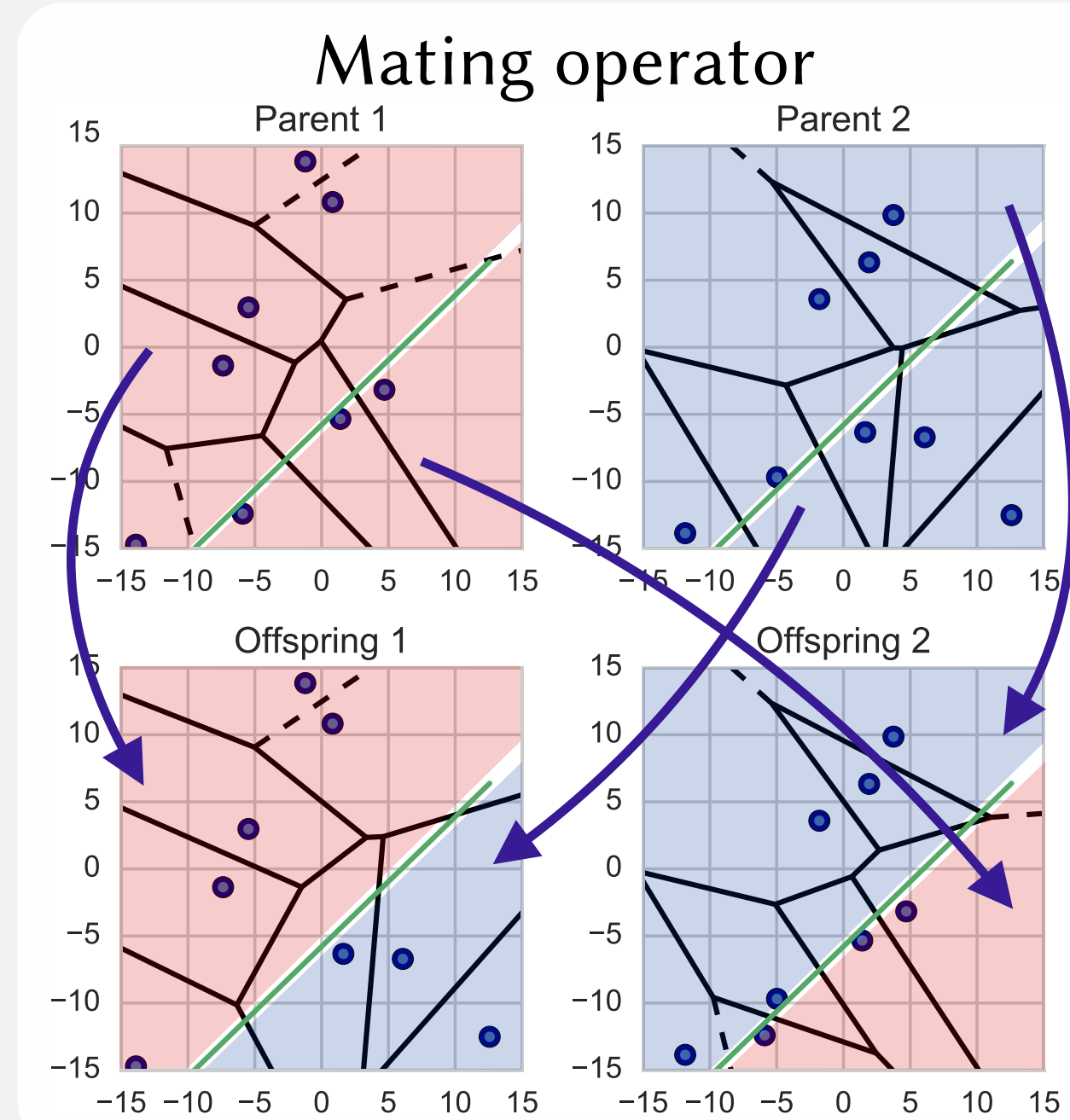
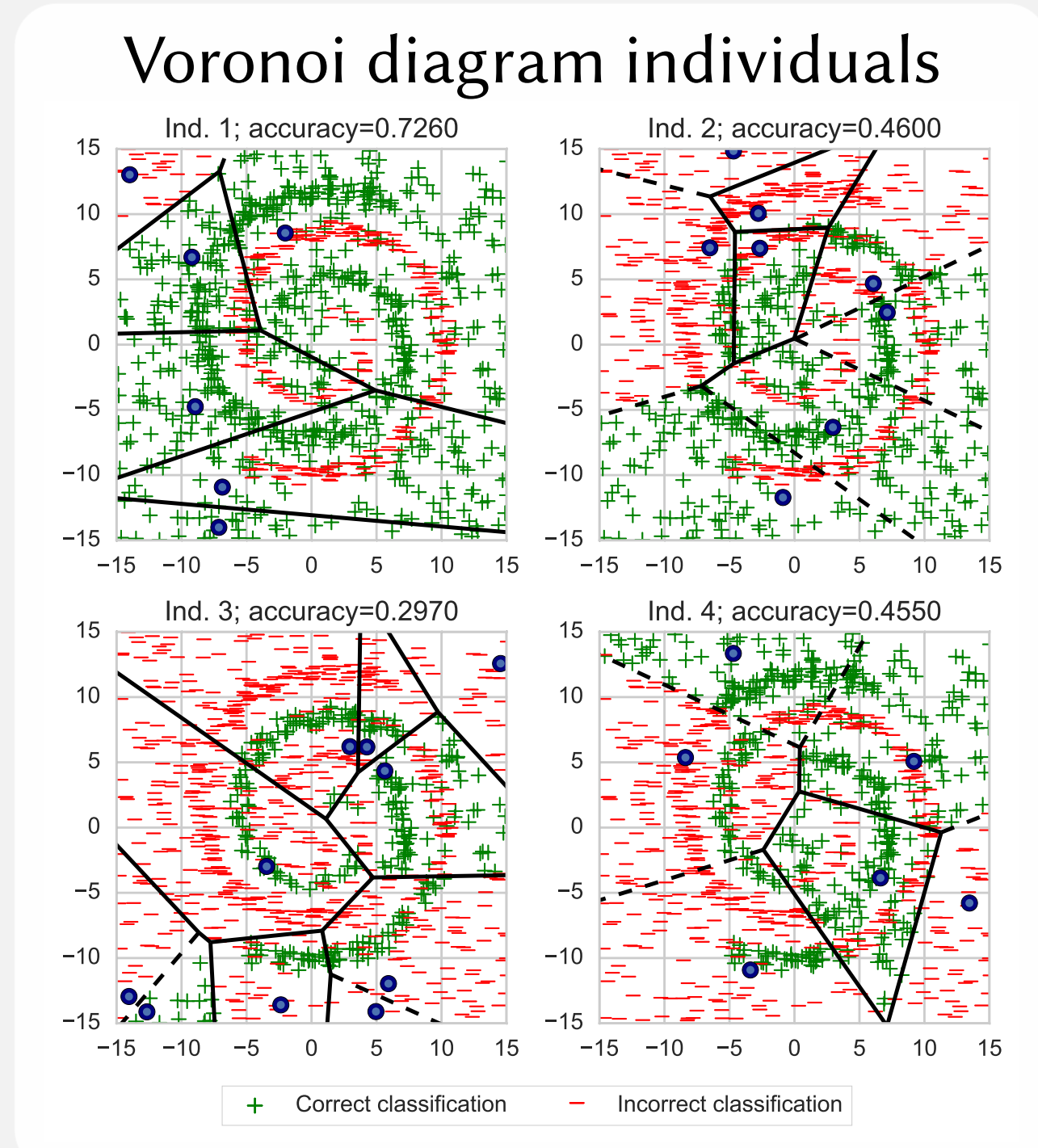
- ▷ Artificial Immune Systems have been derived from existing theories of the functioning of biological immune systems.
- ▷ They create a model that is able to discriminate between normal (self) and abnormal (non-self) objects.
- ▷ This feature makes AISs specially suited for dealing with problems related to anomaly and intrusion detection.

## Voronoi diagram-based Artificial Immune System

VorAIS models the self/non-self using a Voronoi diagram that determines which areas of the problem domain correspond to self or to non-self.

- ▷ Various classification metrics, like accuracy, recall, and specificity, must be taken into account.
- ▷ Multi-objective approach based on non-dominated sorting of NSGA-II.
- ▷ We introduce a mating operator as part of the AIS.

## VorAIS components



**Mutation operator**

```

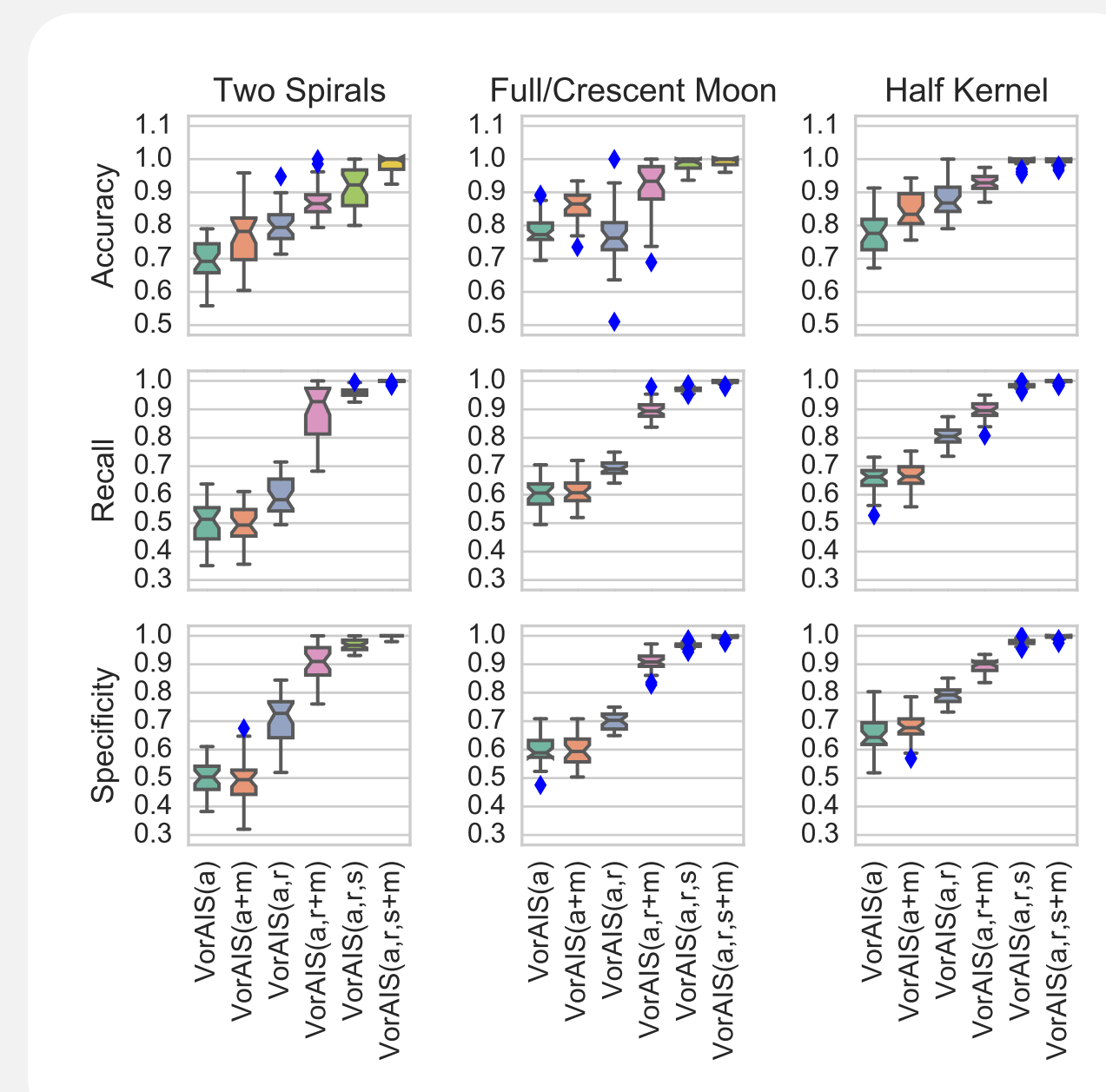
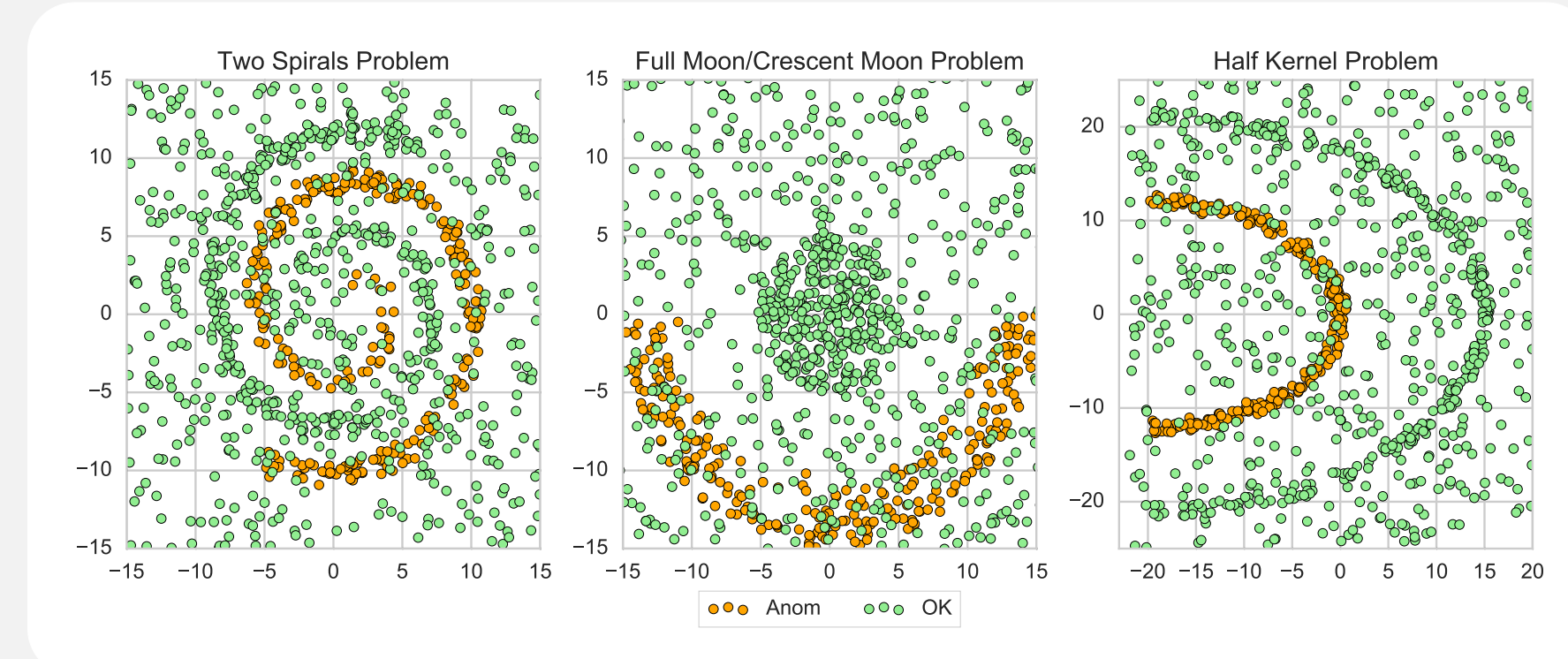
function mutate_voronoi( $\mathcal{I}$ ,  $p_s$ ,  $p_f$ ,  $p_t$ ,  $p_+$ ,  $p_-$ ,  $\eta$ )
  ▷  $\mathcal{I}$ , individual to be mutated.
  ▷  $p_s \in [0, 1]$ , prob. of mutating a site.
  ▷  $p_f \in [0, 1]$ , prob. of mutating a site's feature.
  ▷  $p_t \in [0, 1]$ , prob. of changing the label of a site.
  ▷  $p_+ \in [0, 1]$ , prob. of adding a new site.
  ▷  $p_- \in [0, 1]$ , prob. of removing a site.
  ▷  $\eta \in (0, \infty]$ , learning rate.
  for all  $S \in \mathcal{I}$  do
    if  $U[0, 1] < p_s$  then
      for all  $x \in S$  do
        if  $U[0, 1] < p_f$  then
           $x \leftarrow \text{mutate\_log\_normal}(x, \eta)$ 
        if  $U[0, 1] < p_t$  then
           $S.l \leftarrow \text{switch\_label}(S.l)$ 
      if  $U[0, 1] < p_+$  then
         $\mathcal{I} \leftarrow \mathcal{I} \cup \{\text{random\_site}\}$ 
      if  $U[0, 1] < p_-$  then
         $i \leftarrow U[1, |\mathcal{I}|]$ 
         $\mathcal{I} \leftarrow \mathcal{I} \setminus \{i\}$ 
  return  $\mathcal{I}$ , mutated individual.
    
```

## VorAIS outline

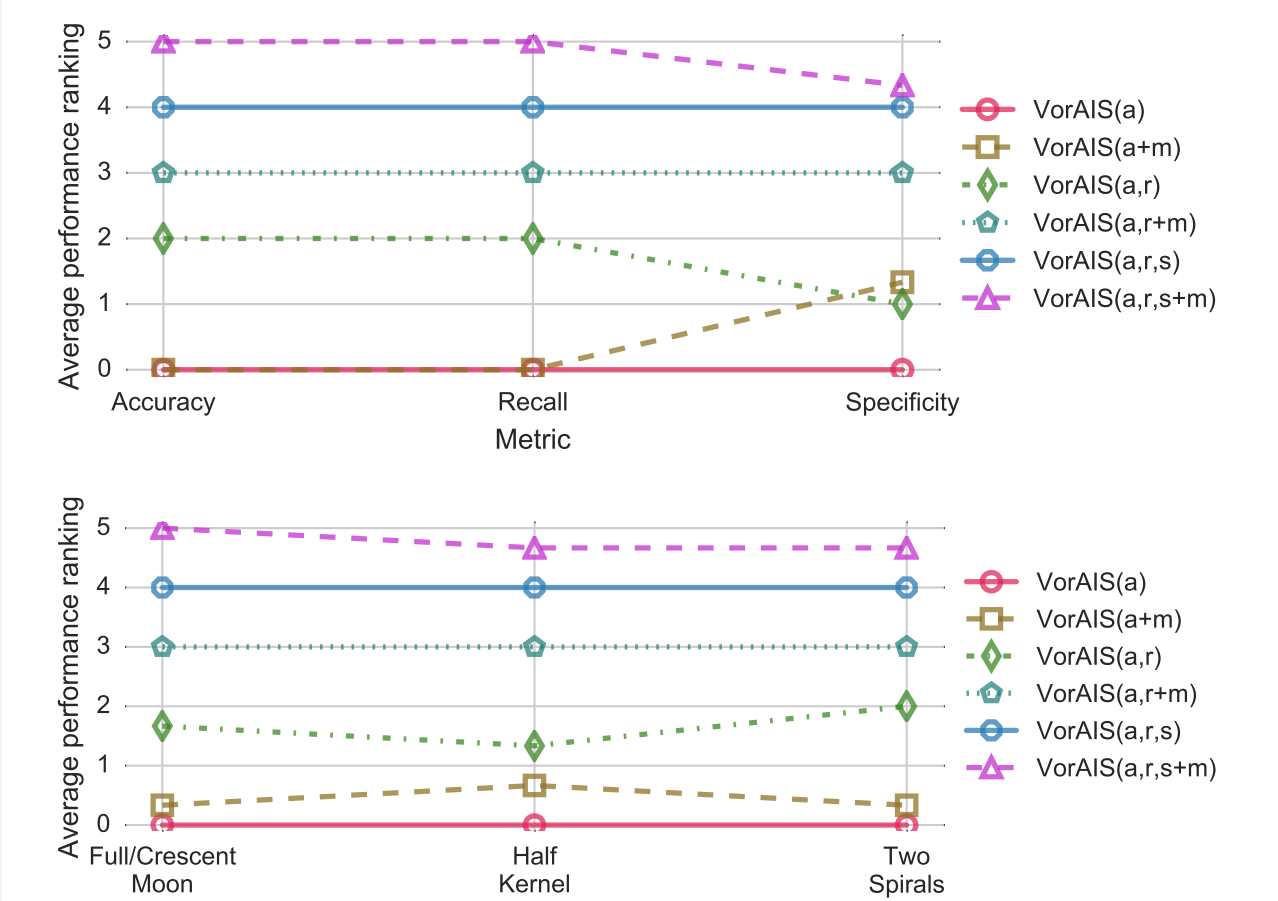
1. Create an initial random population  $\mathcal{P}_0$  of  $n_{\text{pop}}$  individuals.
  2. At iteration  $t$ , individuals in  $\mathcal{P}_t$  are mated and mutated.
  3. An offspring population,  $\mathcal{P}_{\text{off}}$ , with  $n_{\text{off}}$  individuals is created.
  4. From  $\mathcal{P}_t \cup \mathcal{P}_{\text{off}}$  the best  $n_{\text{pop}}$  individuals are selected using non-dominated sorting (with crowding distance).
- Hyperparameters tuned by grid search (see PPSN paper).

## Preliminary study on test problems

- ▷ Influence of the mating operator (+m) and the use of the classification metrics (a, r and s, respectively), on two-dimensional problems.

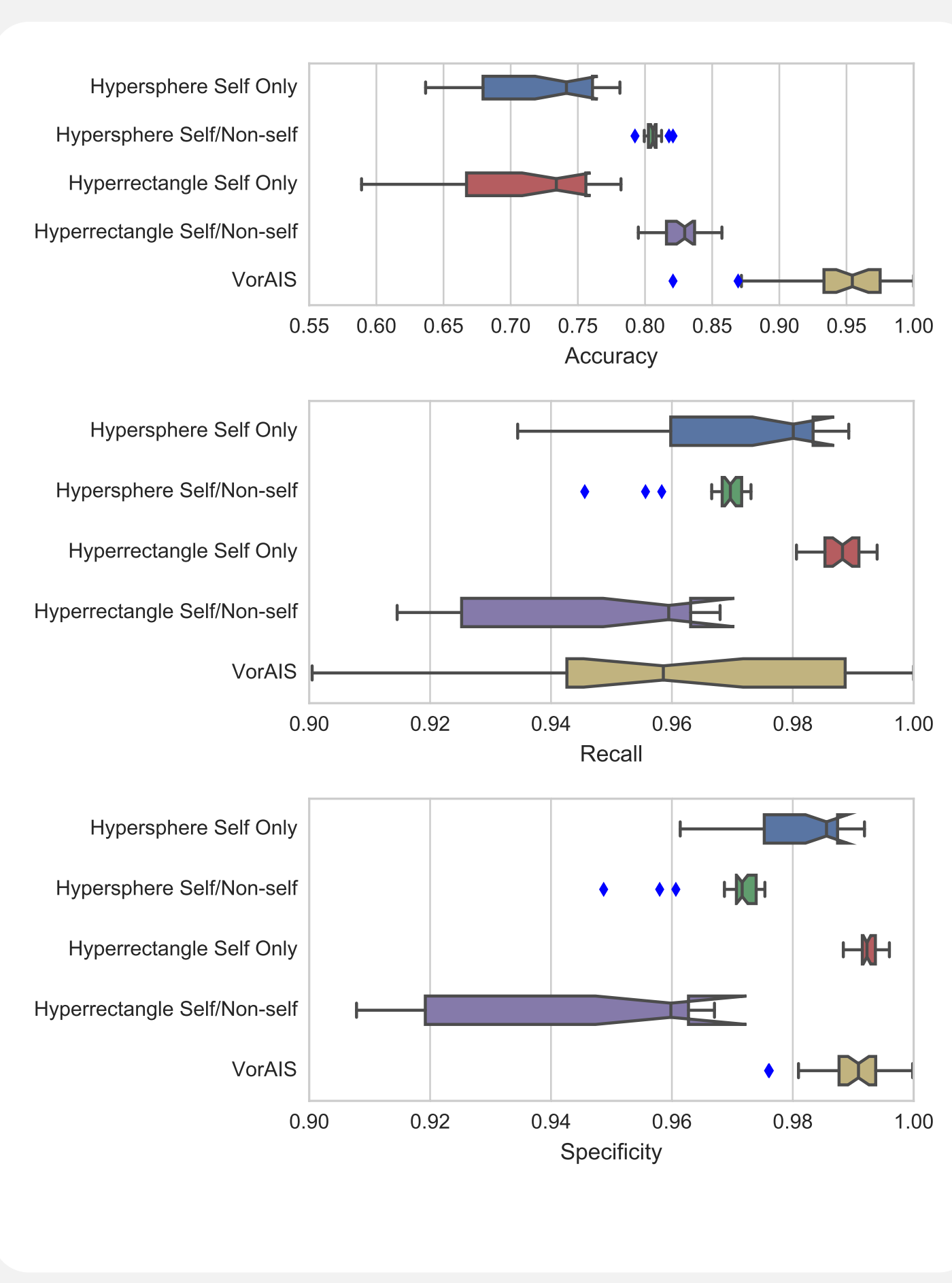


## Bergmann-Hommel tests grouped by problem and metric.



## NSL KDD'99 anomaly detection problem

- ▷ Compare VorAIS with other AISs in a computer network anomaly detection benchmark problem.
- ▷ NSL-KDD'99 has 41—38 numeric and 3 categorical— features and one class attribute describing the nature of the events.



## Bergmann-Hommel tests.

	$NSA_{sp}$	$NSA_{sp}^+$	$NSA_{re}$	$NSA_{re}^+$	VorAIS
<b>Accuracy</b>					
$NSA_{sp}$	×	—	~	—	—
$NSA_{sp}^+$	+	×	+	—	—
$NSA_{re}$	~	—	×	—	—
$NSA_{re}^+$	+	+	+	×	—
VorAIS	+	+	+	+	×
<b>Recall</b>					
$NSA_{sp}$	×	+	—	+	~
$NSA_{sp}^+$	—	×	—	+	~
$NSA_{re}$	+	+	×	+	+
$NSA_{re}^+$	—	—	—	×	—
VorAIS	~	~	—	+	×
<b>Specificity</b>					
$NSA_{sp}$	×	+	—	+	—
$NSA_{sp}^+$	—	×	—	+	—
$NSA_{re}$	+	+	×	+	+
$NSA_{re}^+$	—	—	—	×	—
VorAIS	+	+	—	+	×

## Final remarks

- ▷ We have obtained a performance comparable with the state of the art but adequate classification performance is not enough.
- ▷ It is necessary to create a compact representation of the 'normal' data.
- ▷ We developed custom objective functions that rely on volume-based approaches.

L. Martí, A. Fansi-Tchango, L. Navarro, and M. Schoenauer, *Anomaly detection with the Voronoi diagram evolutionary algorithm*, in Proceedings of the 14<sup>th</sup> International Conference on Parallel Problem Solving from Nature (PPSN XIV), Edinburgh, UK: Springer, 2016.