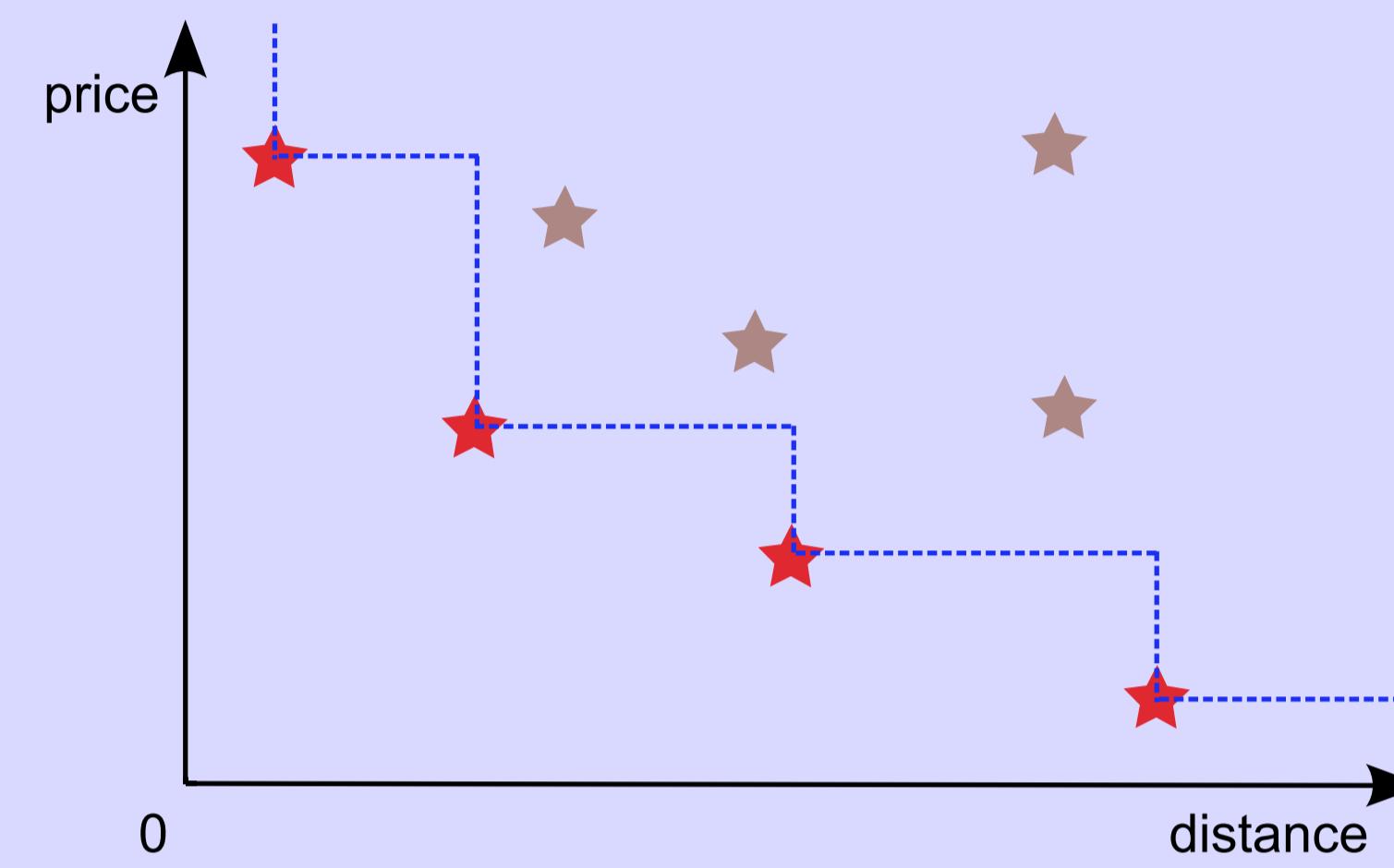


# INTERACTIVE RANKING OF SKYLINES USING MACHINE LEARNING TECHNIQUES

Weiwei Cheng, Eyke Hüllermeier, Bernhard Seeger, Ilya Vladimirskiy  
 Department of Mathematics and Computer Science  
 Marburg University, Germany



## Ranking the Skyline

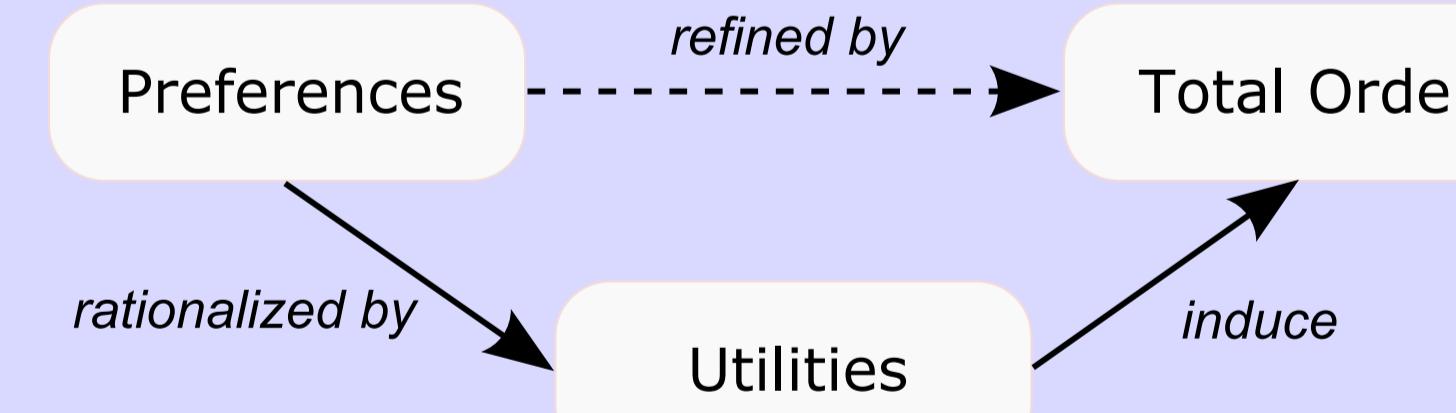


The *skyline* operator maps a finite set  $\mathcal{O}$  of objects, each characterized in terms of a fixed number of features (criteria), to the subset of Pareto-optimal elements:

$$P(\mathcal{O}) \stackrel{\text{df}}{=} \{ \mathbf{o} \in \mathcal{O} \mid \{ \mathbf{o}' \in \mathcal{O} \mid \mathbf{o} \prec \mathbf{o}' \} = \emptyset \}$$

Important problem:  $P(\mathcal{O})$  may become huge, especially in high dimensions!

Ranking the skyline via a (latent) utility function:



- A utility function  $U(\cdot)$  assigns a real utility degree to each object  $\mathbf{a} = (a_1 \dots a_d) \in \mathcal{O}; U(\mathbf{a}) < U(\mathbf{b})$  means that the user strictly prefers  $\mathbf{b}$  to  $\mathbf{a}$ .
- Utility degrees induce a total order; thus, a ranking can be presented instead of an unsorted answer set.
- User feedback is used to improve ranking quality.

## Algorithm Design

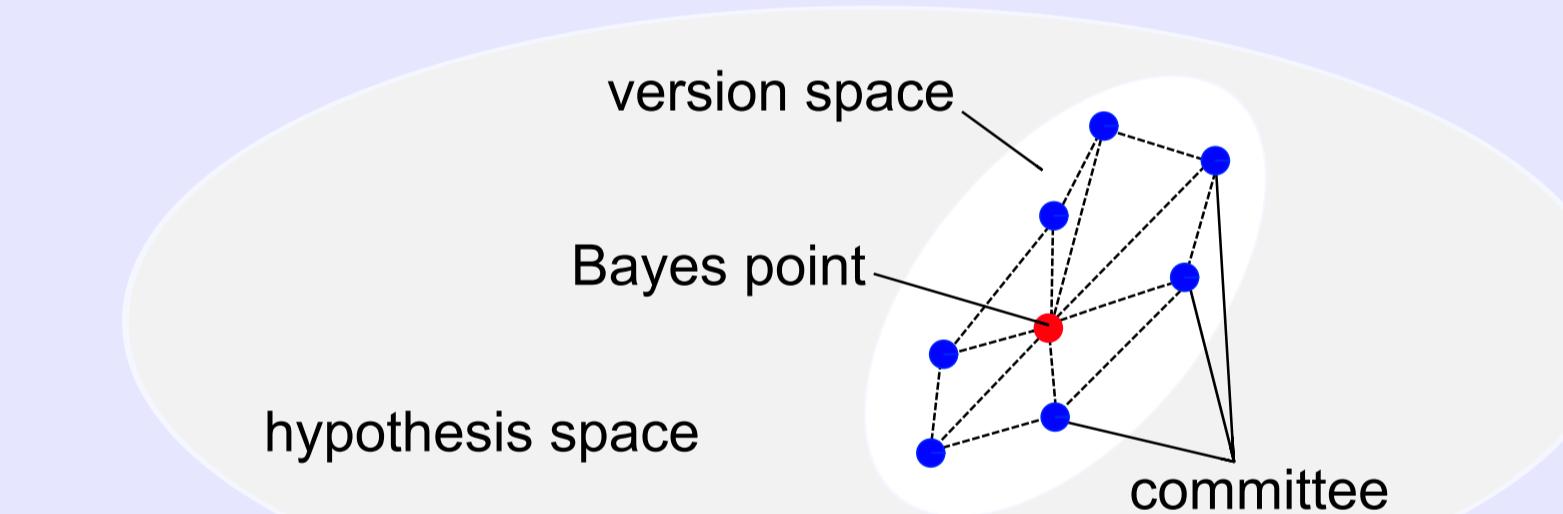
**Base Learner:** Noise tolerant perceptron with margin.

**Training Data:** A set of revealed (pairwise) preferences  $\mathbf{a} \prec \mathbf{b}$ , turned into positive and negative examples for classification.

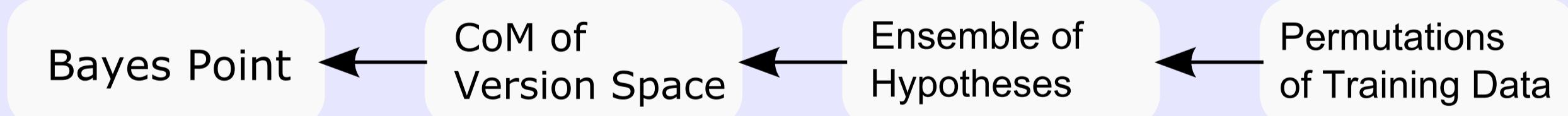
**Monotonicity:**  $\mathbf{a} \geq \mathbf{b} \Rightarrow U(\mathbf{a}) \geq U(\mathbf{b})$  must be guaranteed for all  $\mathbf{a}, \mathbf{b} \in \mathcal{O}$ .

**Utility:** Linear model  $U(\mathbf{a}) = \langle \mathbf{w}, \mathbf{a} \rangle = w_1 a_1 + \dots + w_d a_d$  (monotonicity holds if  $\mathbf{w} \geq 0$ ) and kernalized version.

**Bayes Point Machine:**



Approximation of the Bayes point by the center of mass of version space.

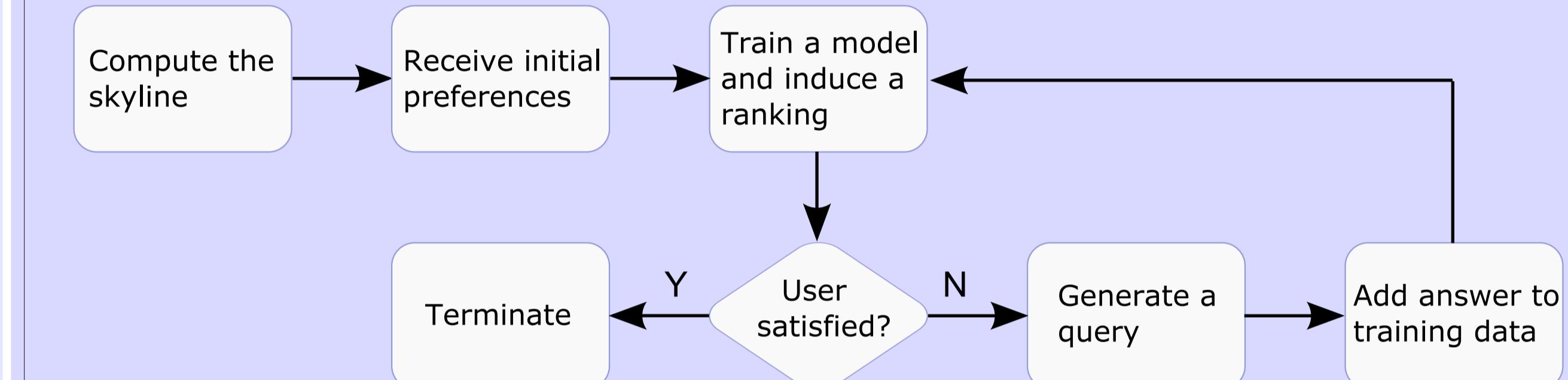


**Active Learning Strategy:**

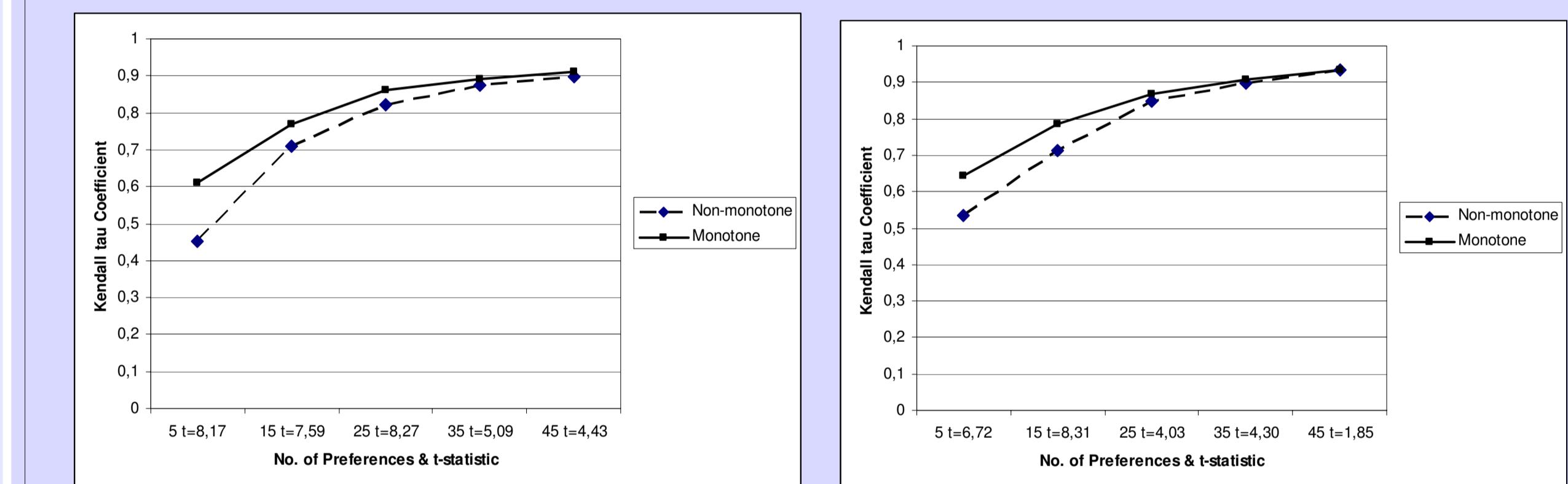
1. Constitute a committee of learners.
2. Find two maximally conflicting learners.
3. For each learner, generate a corresponding ranking.  
Return the first discordant pair as a query. Add the answer to the preference set.
4. Retrain the committee on the enlarged preference set and go to step 2.

## Experimental Results

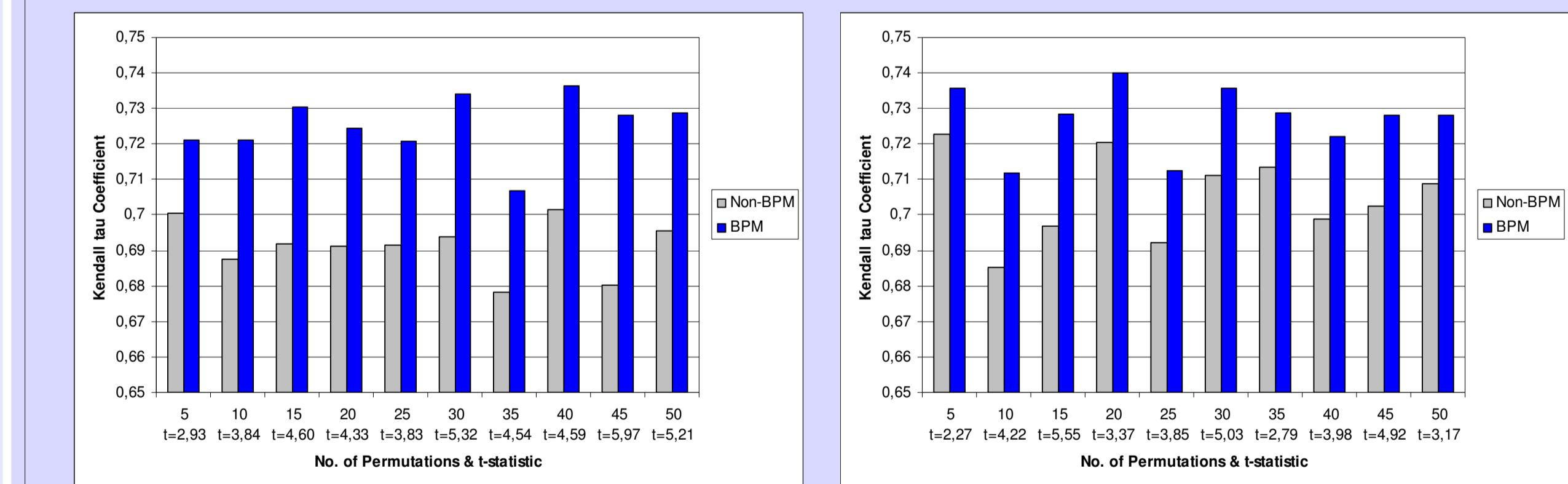
**Workflow:**



**Monotone vs. non-monotone learning:**



**Ensemble (Bayes point machine) vs. single learner:**



**Active vs. non-active learning:**

