

SHIFTTREE:

AN INTERPRETABLE MODEL-BASED APPROACH FOR TIME SERIES CLASSIFICATION

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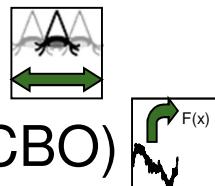
ECML/PKDD, 6TH SEPTEMBER 2011, ATHENS

OUTLINE

- General concept
- Task & adaptation
- Labeling & learning
- Evaluation
- Forest methods
- Conclusion

GENERAL CONCEPT

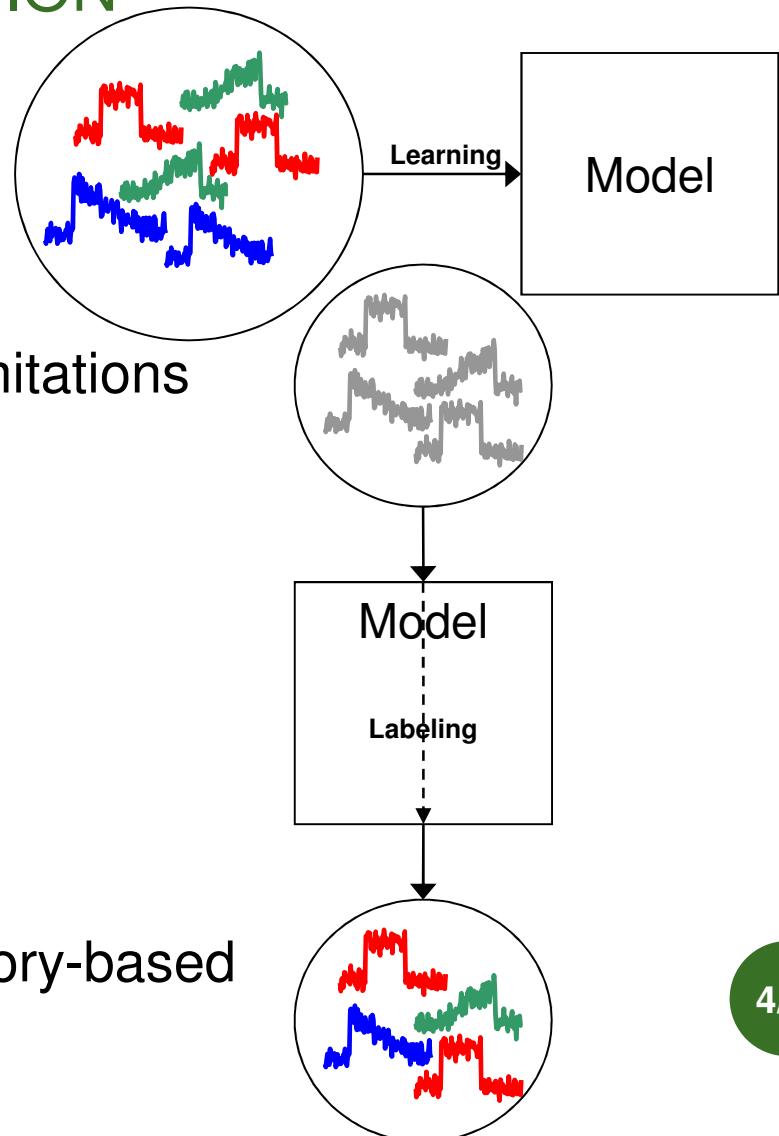
- Not limited to time series
 - Time series
 - Semi-structured data
 - Graphs
- Two questions:
 - „Where to look at?”
 - „What to observe?”
- Operator families
 - EyeShifter Operator(s) (ESO)
 - ConditionBuilder Operators (CBO)
- Dynamic attributes
- Model: sequence of simple operators / rules



TIME SERIES CLASSIFICATION

- Time series

- With one observed variable
- Evenly sampled
- The algorithm has no such limitations



- Standard classification task

- Focusing on accuracy

- Goals

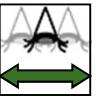
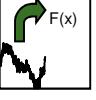
- Satisfying accuracy
- Model-based instead of memory-based
- Interpretable models

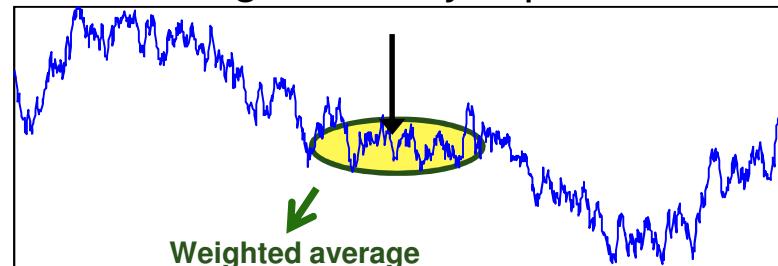
EXPLAINING THE GOALS

- Why model-based?
 - Labeling is much faster ✓
 - Can learn more general properties of the classes ✓
 - Needs more training samples ✗

- What is interpretability good for?
 - Getting user trust ✓
 - Helping in understanding the data ✓

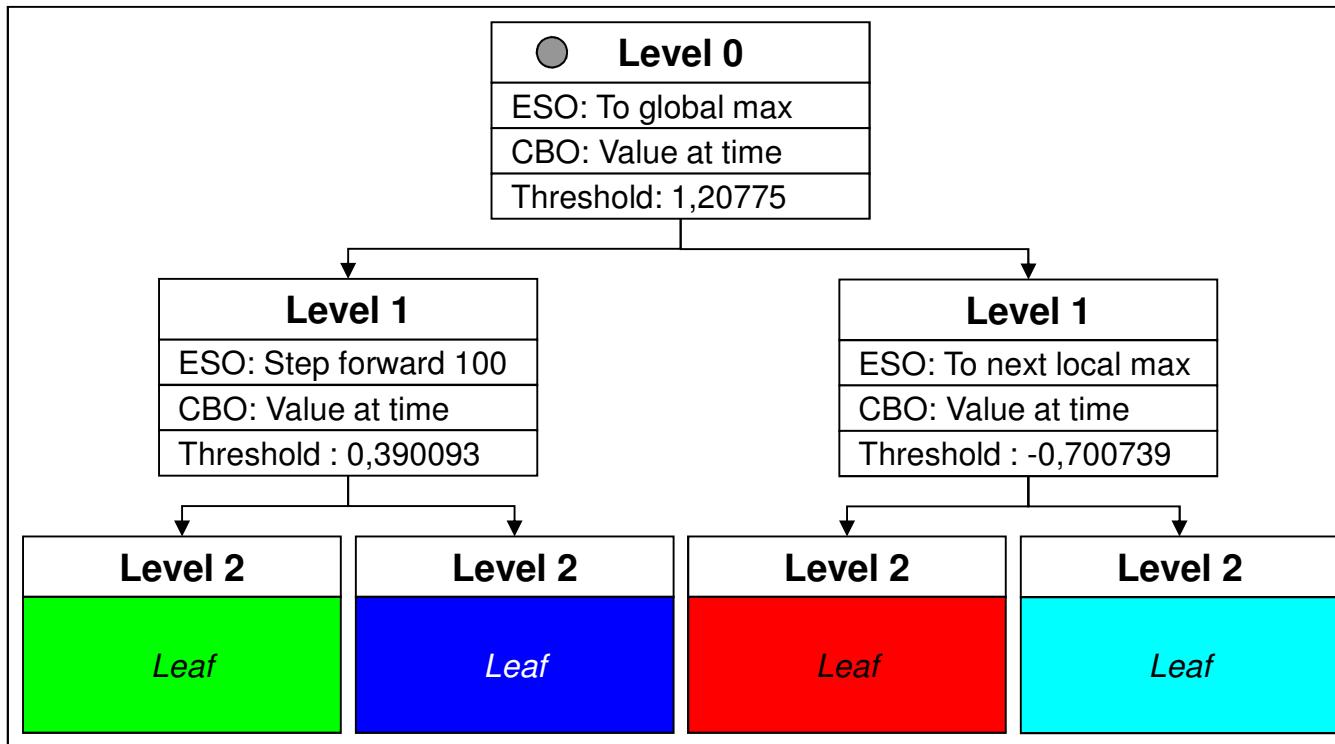
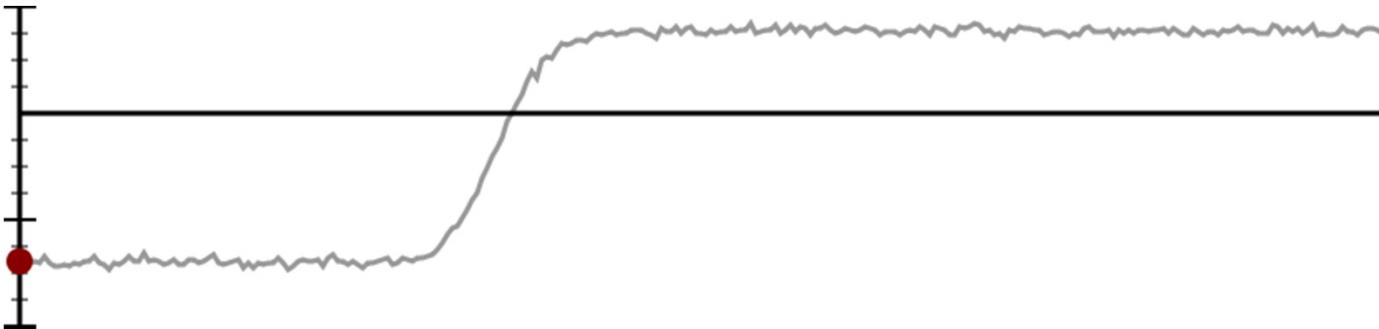
CONCEPT APPLIED TO TIME SERIES

- Dynamic attributes of time series
 - EyeShifter Operator (ESO): „Where to look at?”
 - Moves a cursor along the time axis
 - To a specified point of the series
 - E.g.: „To the next local minimum”, „100 steps ahead”, etc.
 - Note: result of operator sequence depends on the order
 - ConditionBuilder Operator (CBO): „What to observe?”
 - Computes the dynamic attribute
 - E.g.: „Value at the given time”, „Length of the jump”, etc.

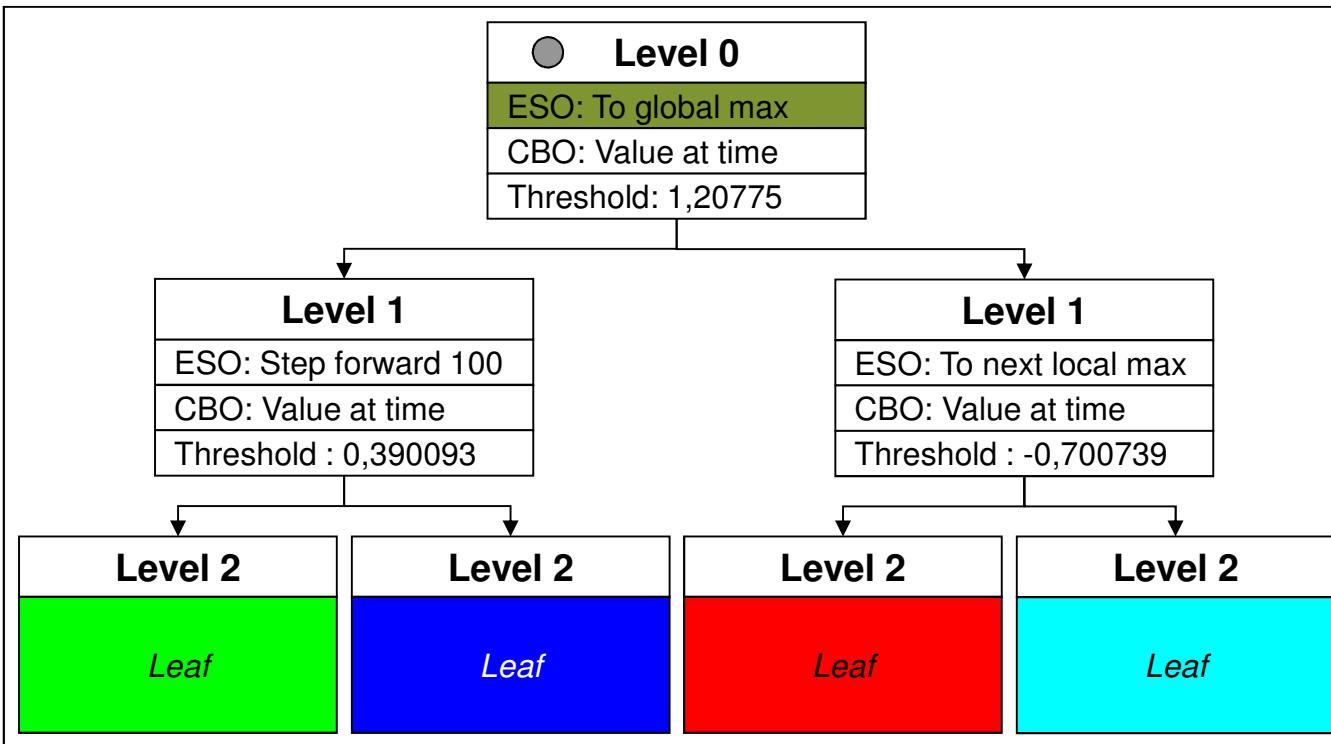
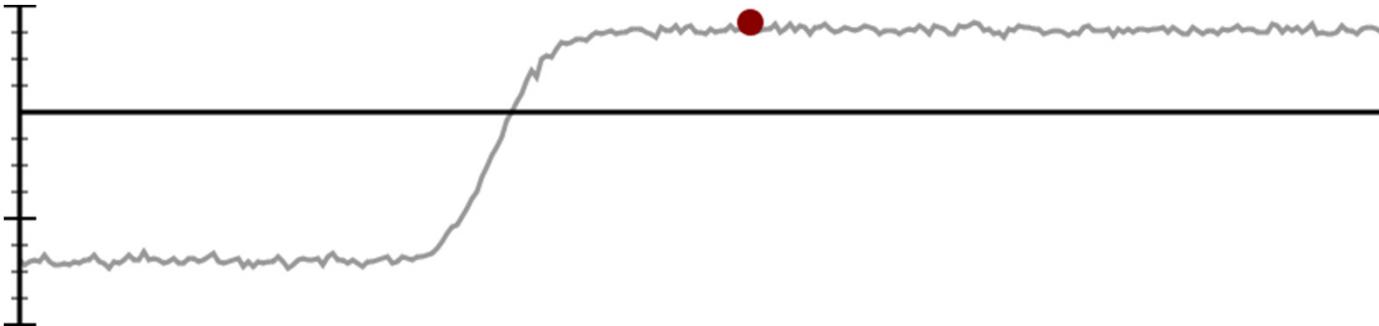


- Decision tree as model
 - Works well with the dynamic attribute concept
 - Operator sequence from root to leaf

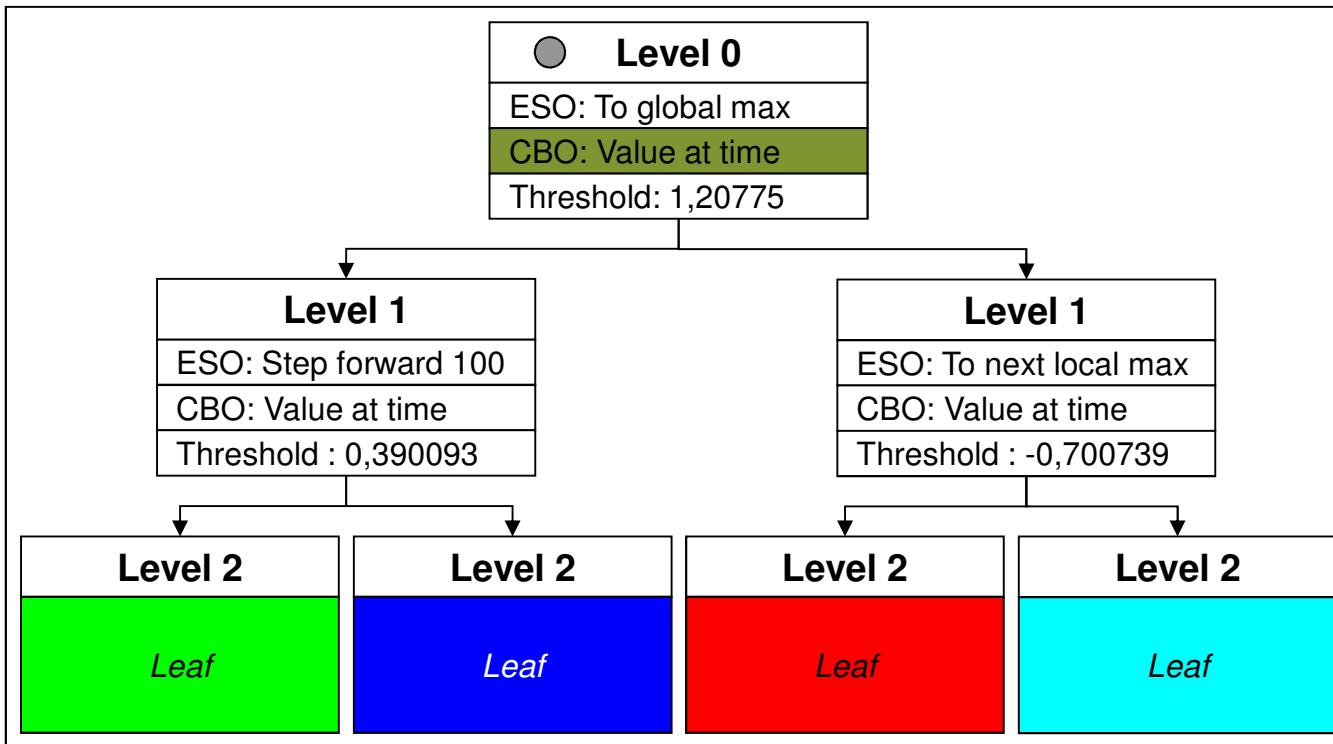
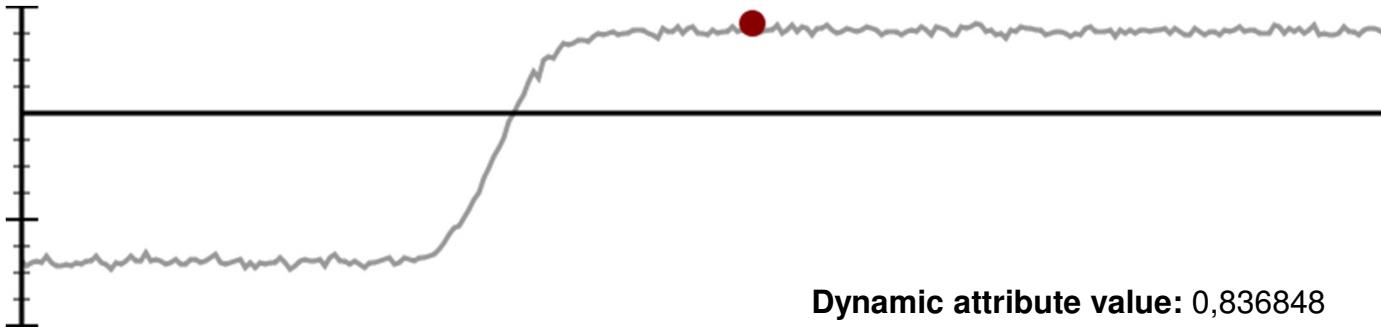
LABELING



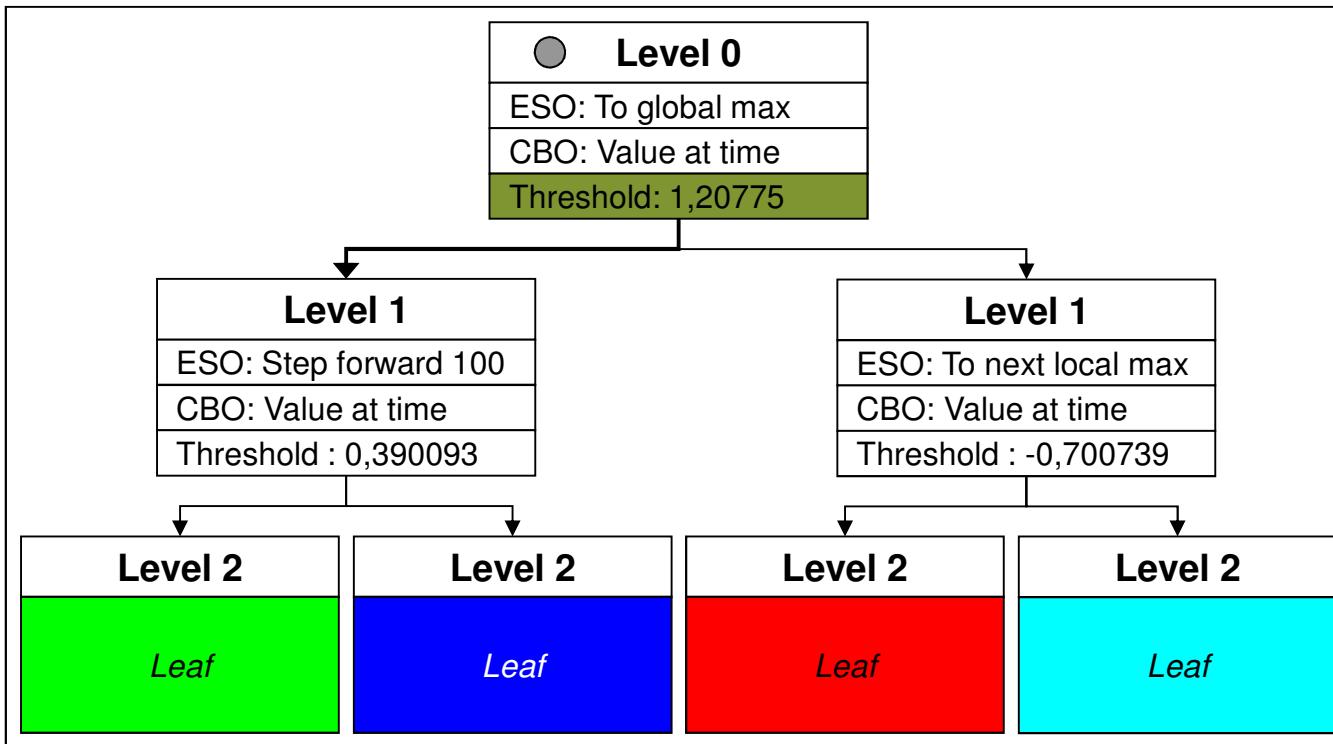
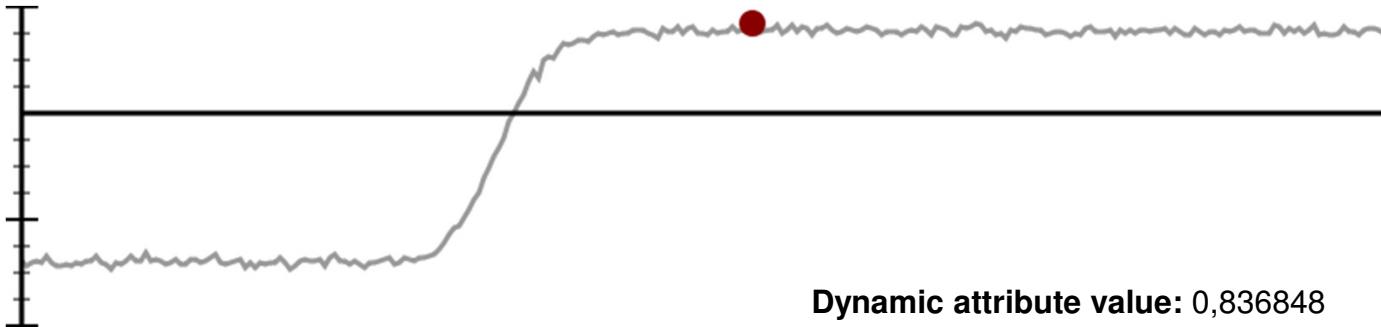
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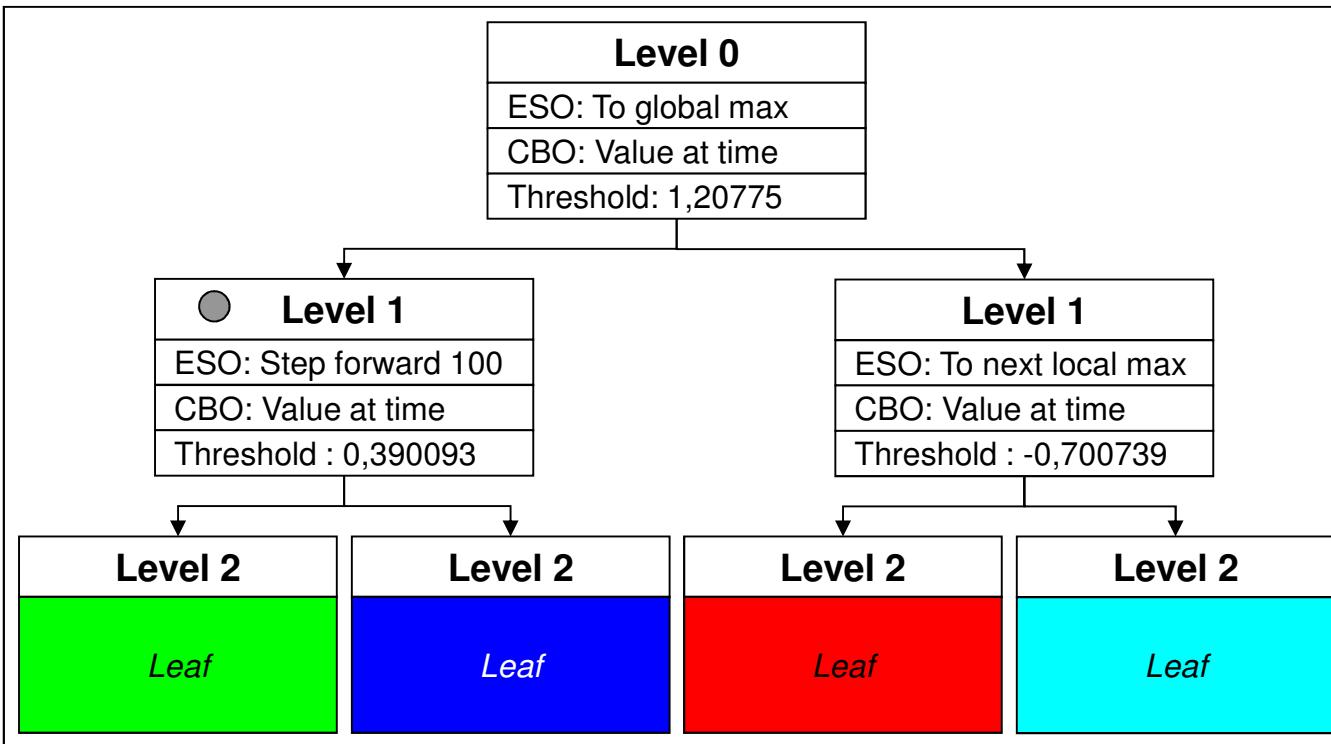
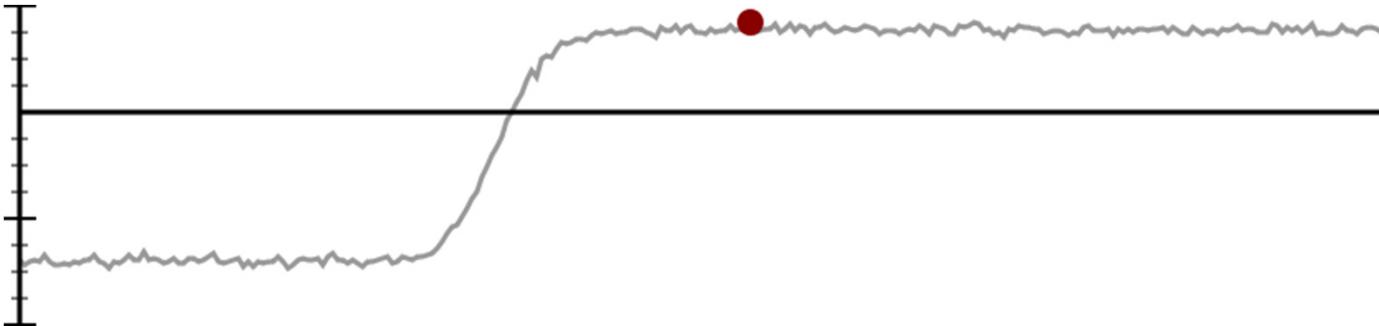
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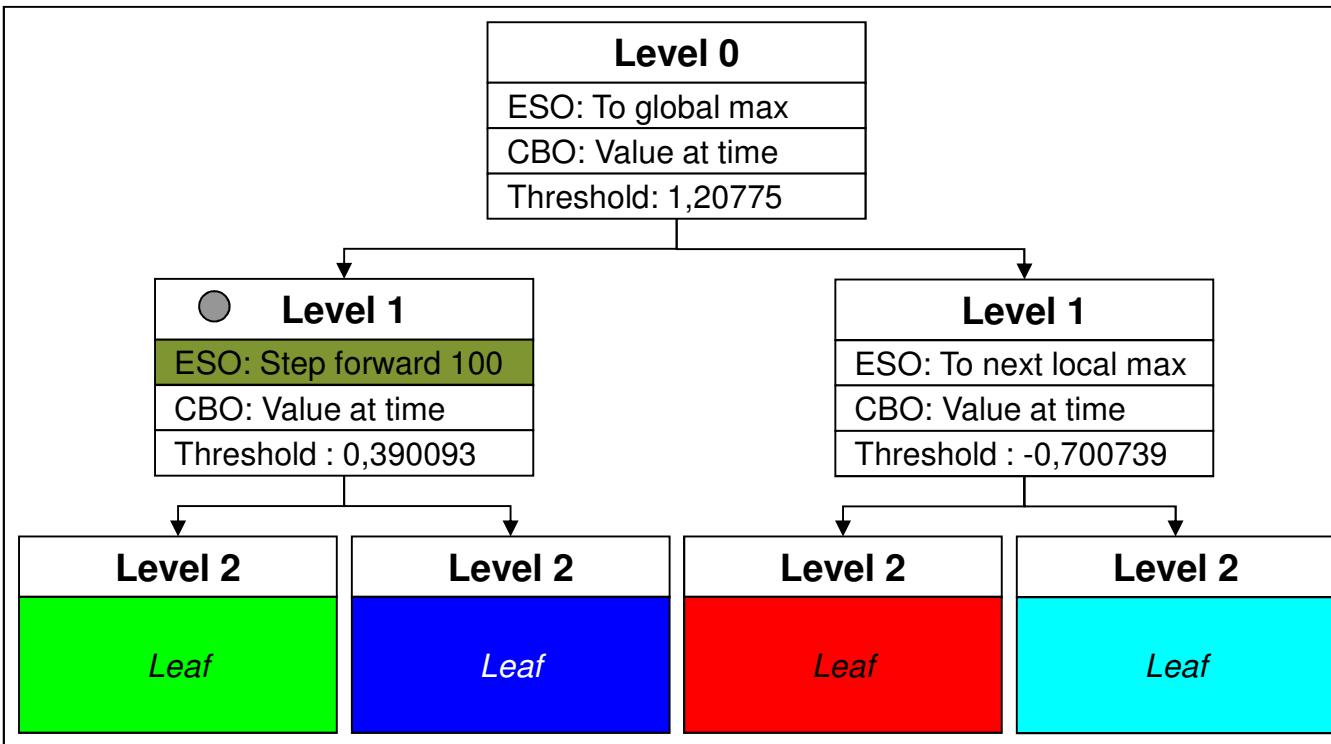
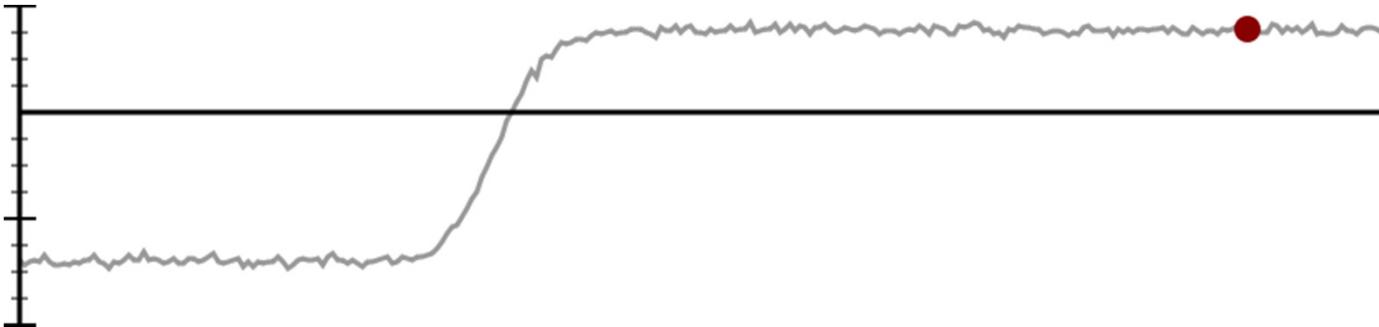
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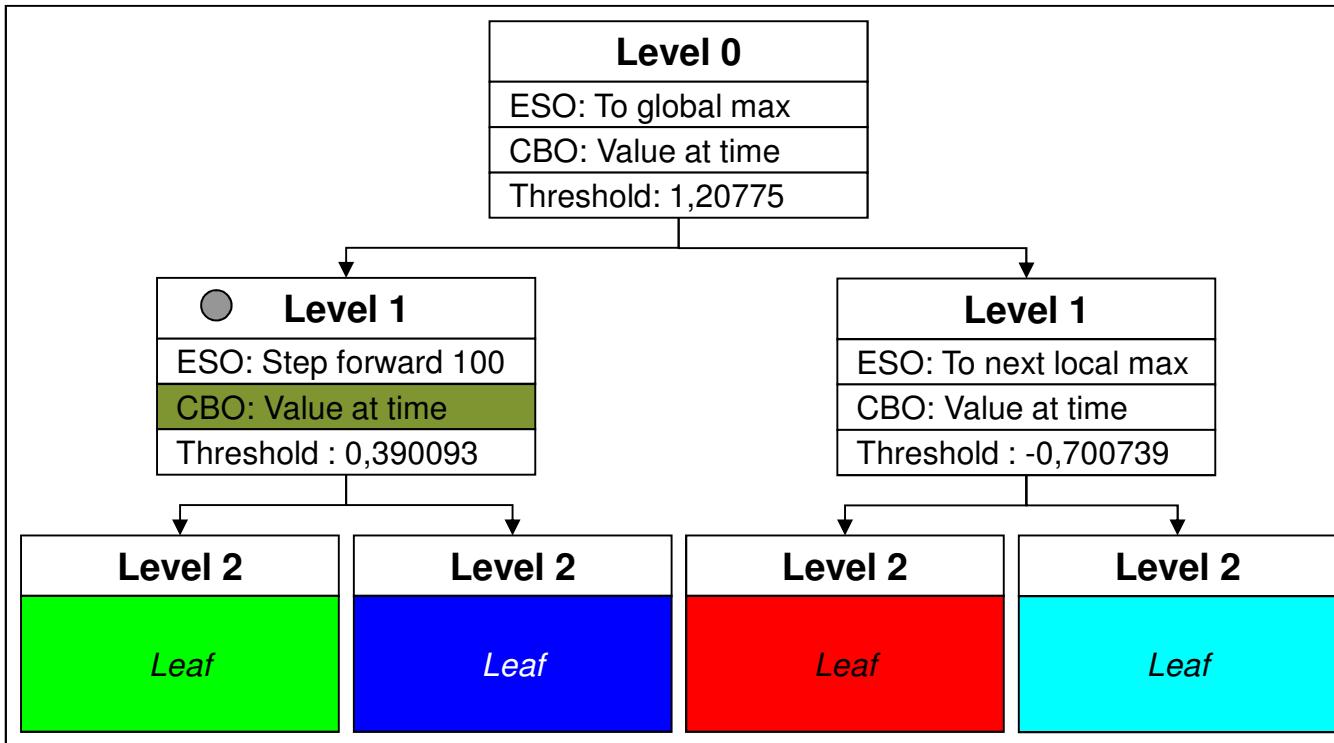
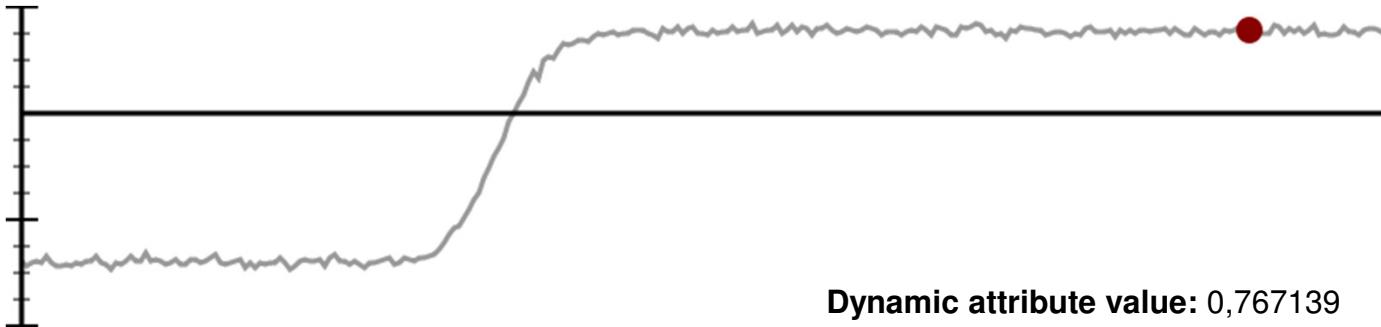
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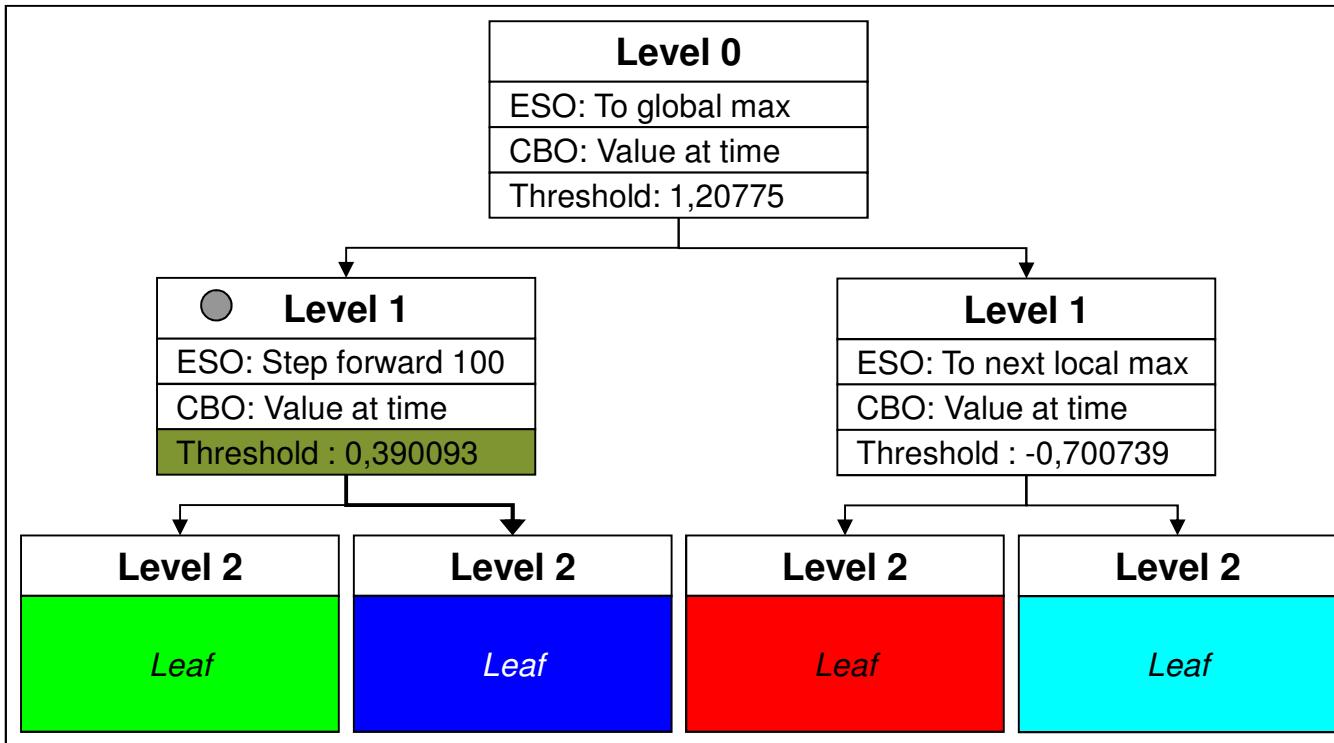
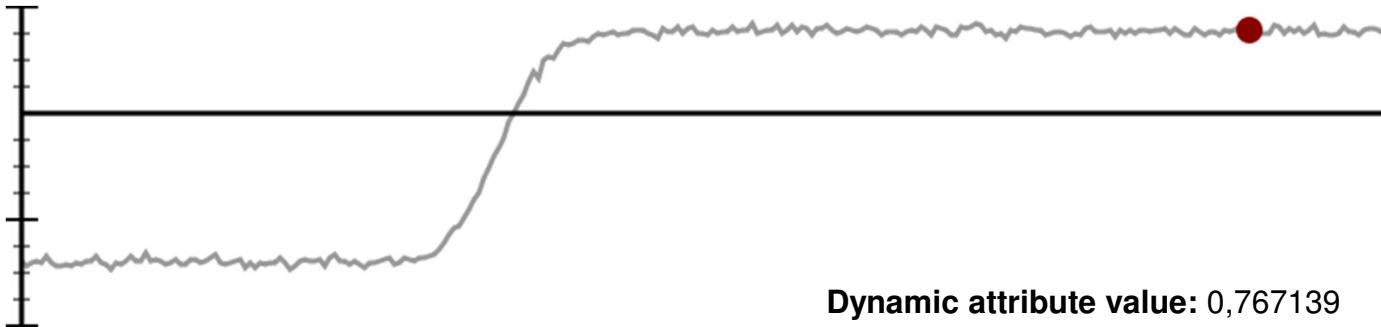
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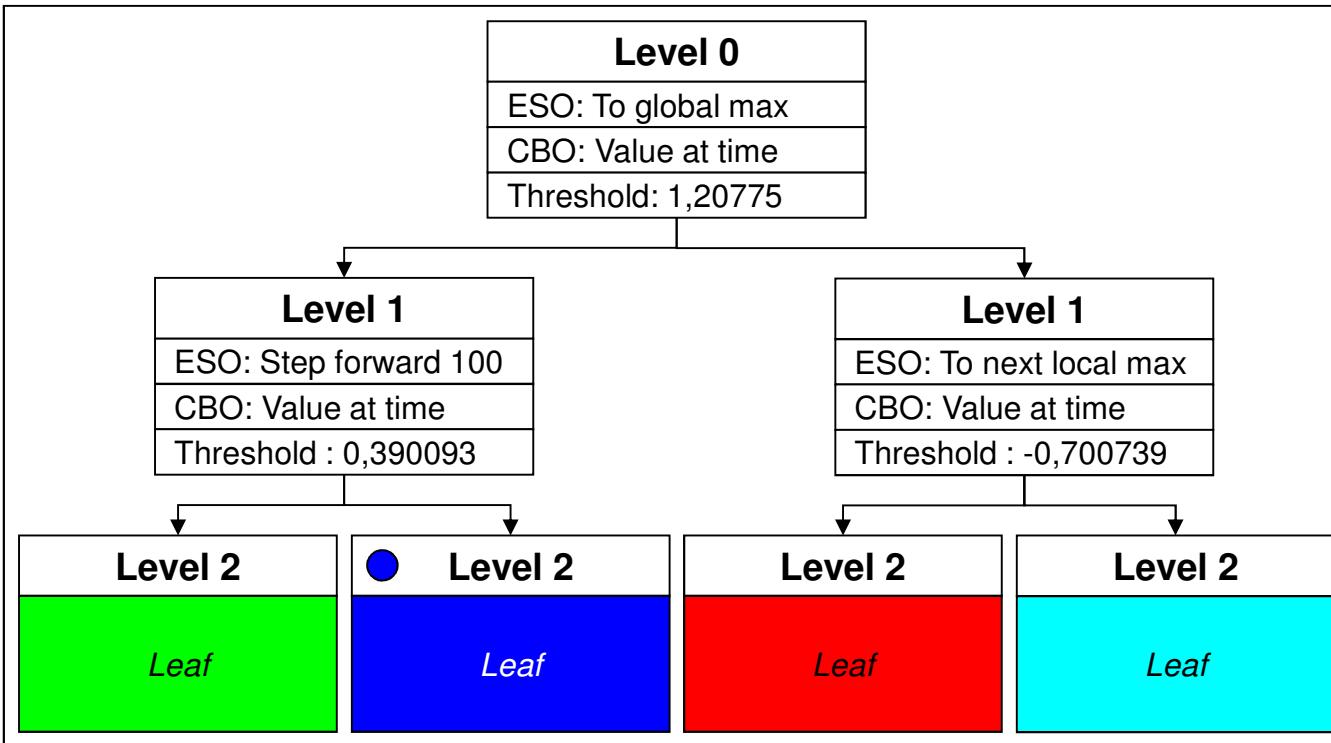
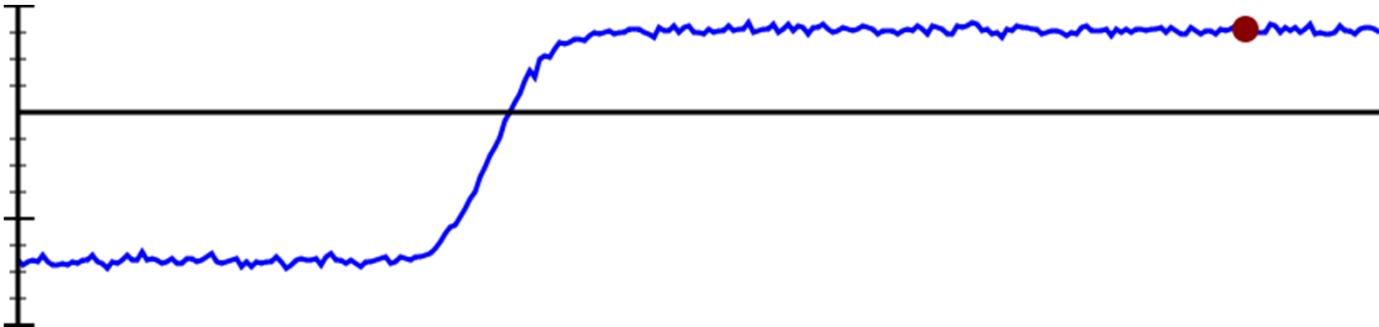
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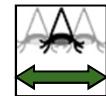
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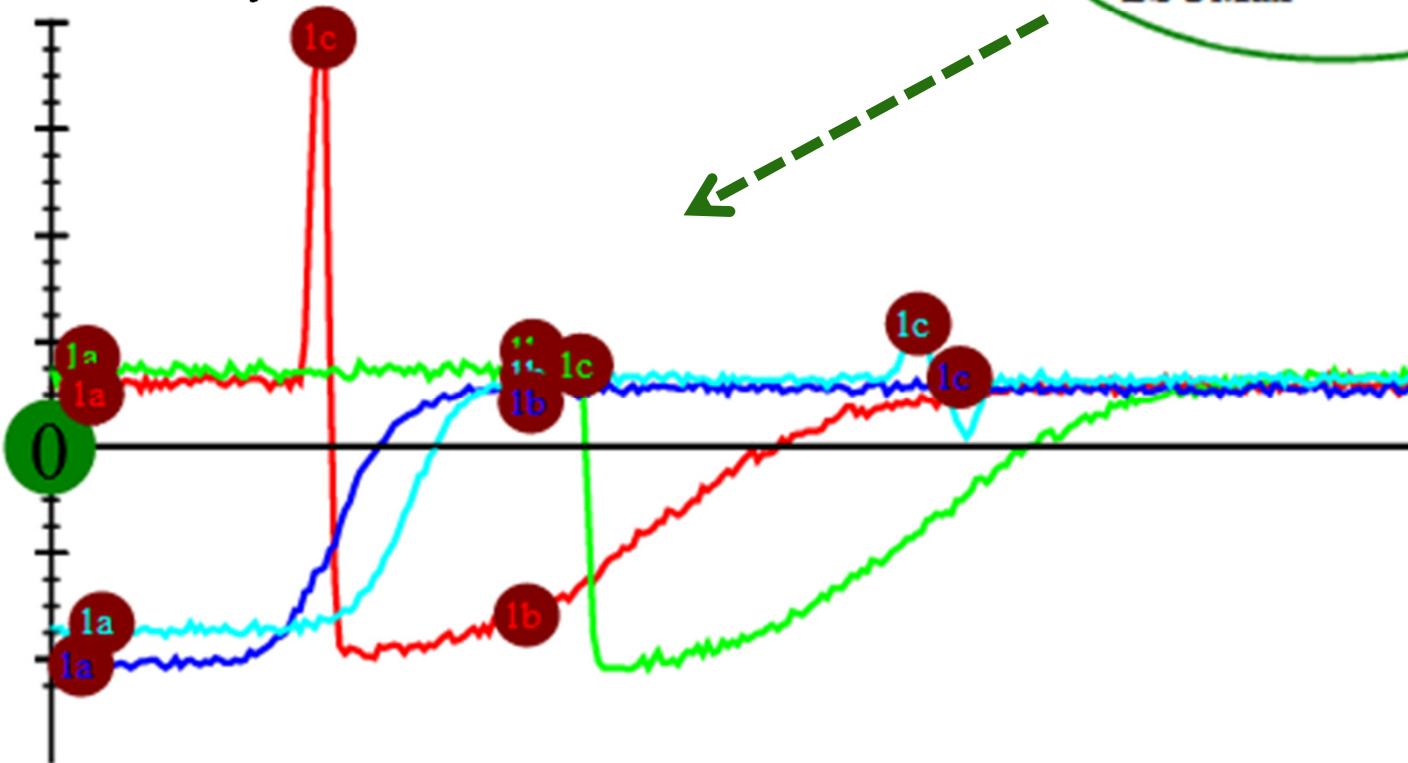
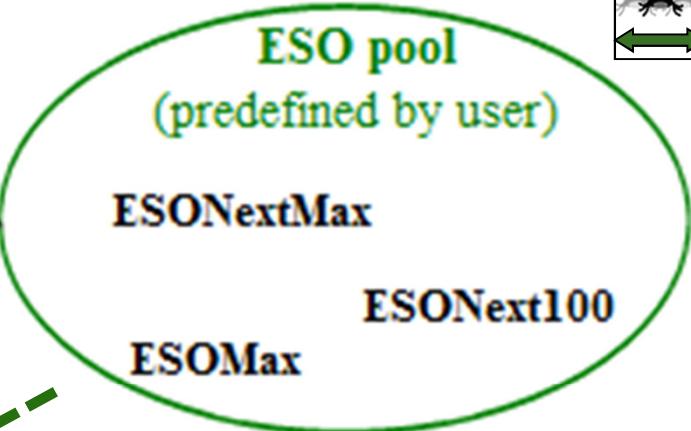
LABELING



LEARNING (1/3)



- Operator pool definition: ESOs,
- Root node
- Cursor starts at the beginning
 - May be overridden



LEARNING (2/3)

- Available dynamic attributes (CBO pool)

- At/around reachable positions

- Selecting a...

- Attribute
- Threshold value

} Minimize weighted child node entropy

Possible dynamic attributes
(operator pairs) in root node

Value at

1a

Average around

1a

using $R = 20$

Value at

1b

Average around

1b

using $R = 20$

Value at

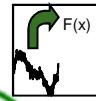
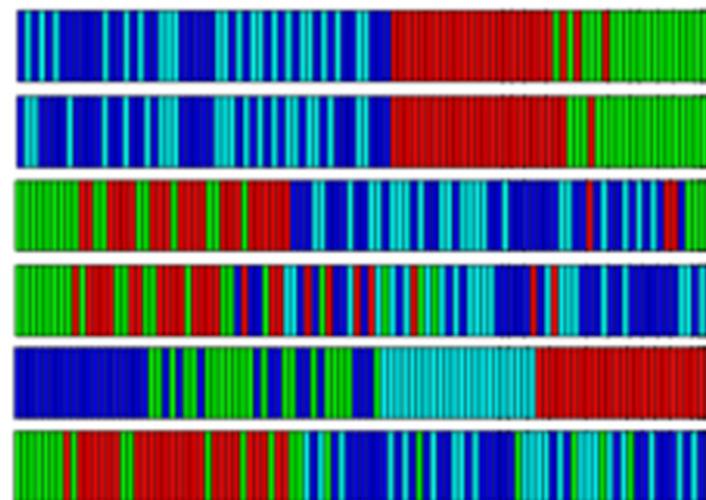
1c

Average around

1c

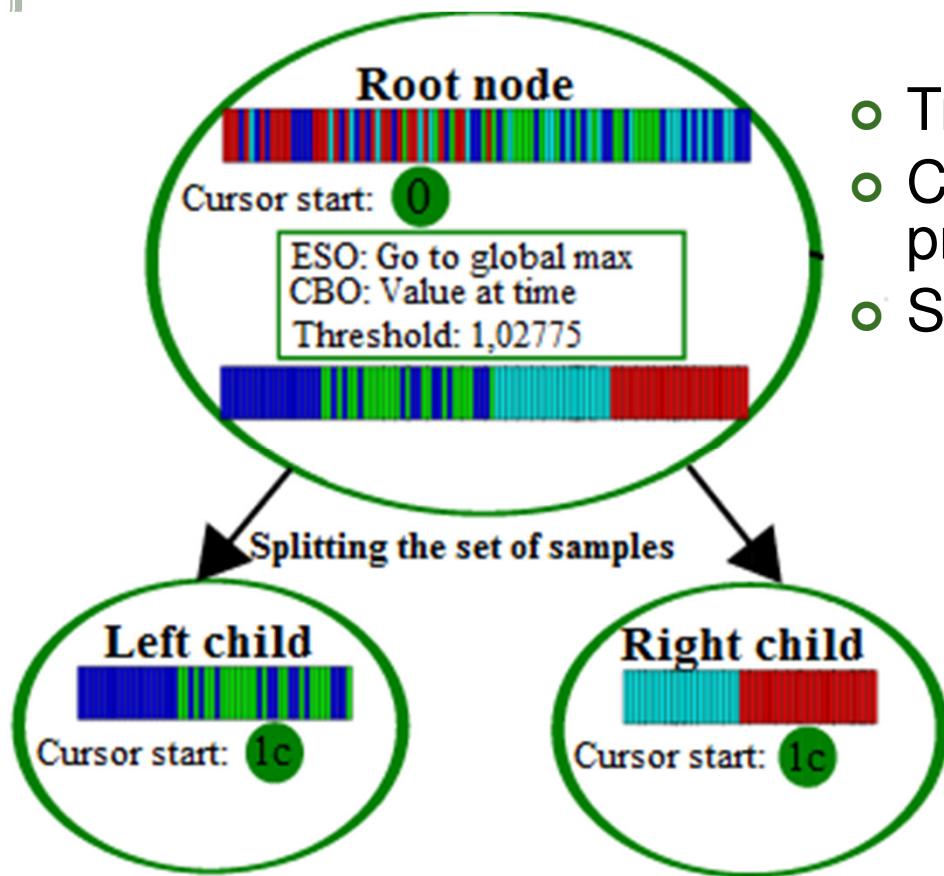
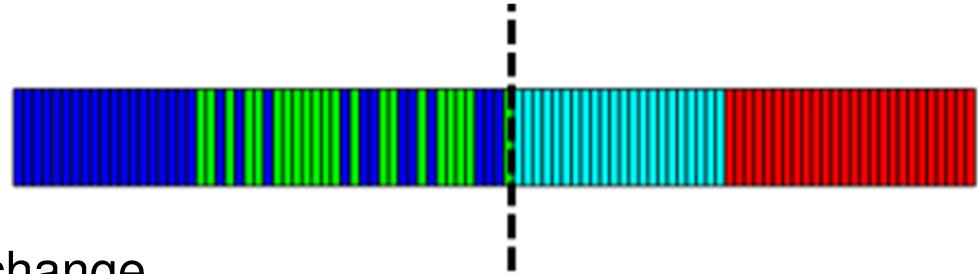
using $R = 20$

Ordering of the samples in the node
by dynamic attributes



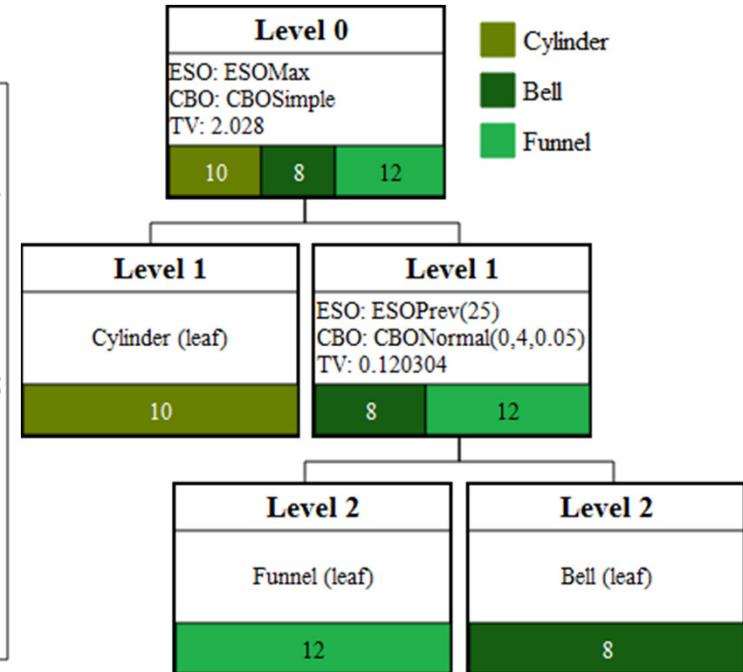
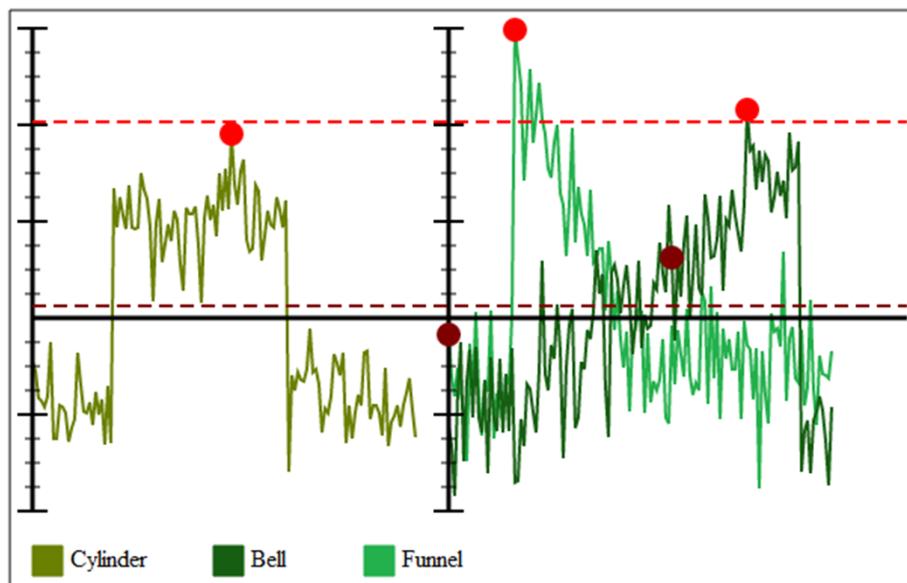
LEARNING (3/3)

- Best split selected
- Cursor is moved by ESO
 - Reachable positions will change



- Train set split
- Child nodes continue the learning process
- Stop: homogenous nodes

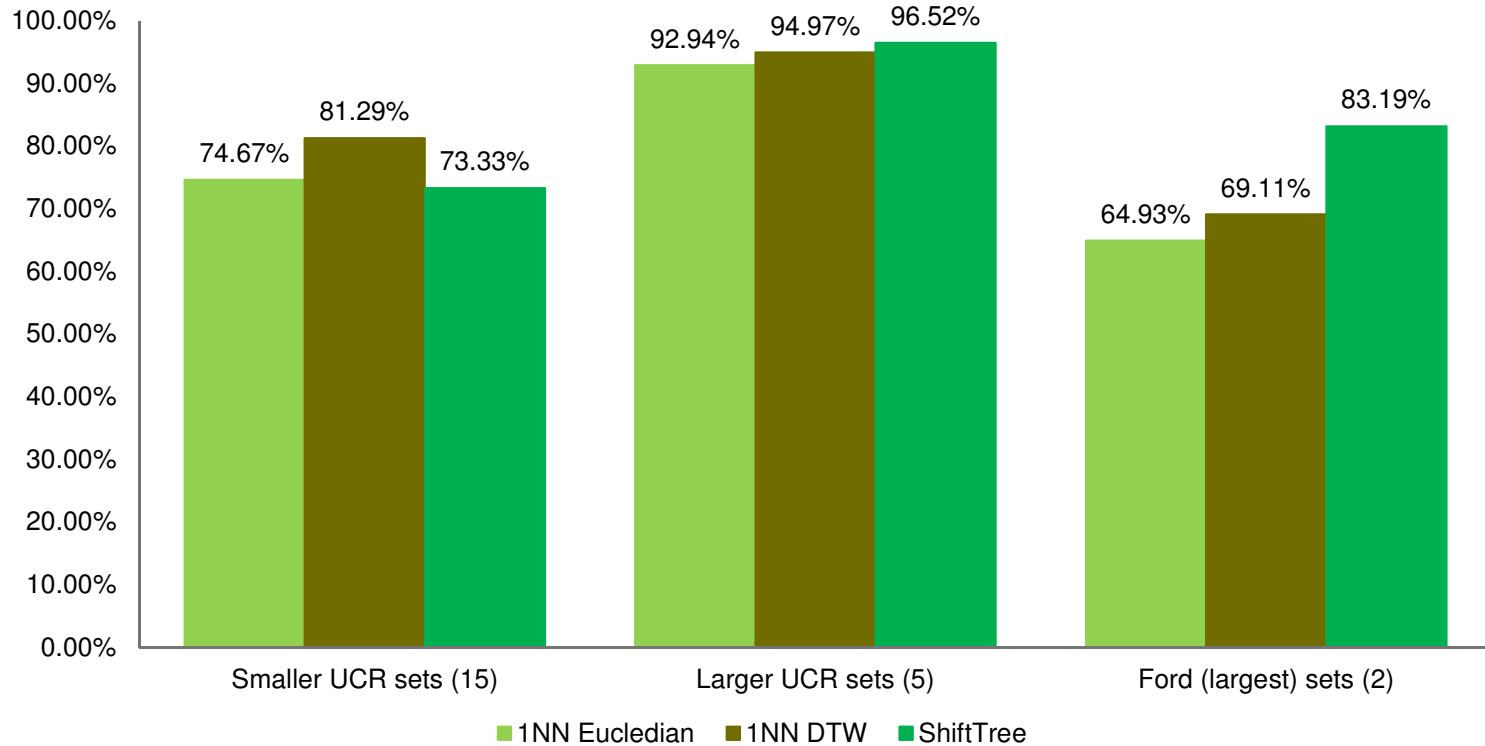
INTERPRETABILITY



- Depends on the operators
- Helps understanding the data
- E.g.: CBF dataset
 - Z-normalized, 3 class: Cylinder, Bell, Funnel
 - Distinguish cylinder from bell and funnel by global maxima
 - The data is z-normalized (standardized)
 - Distinguish bell from funnel by stepping back 25 steps + noise filtering through weighted average
 - On which side is the peak

PERFORMANCE OF THE ALGORITHM

- Databases
 - UCR: mostly smaller data sets (20)
 - Ford: larger data sets (2)
- No optimizations in the experiments
- Performance
 - Better on larger data sets (model-based)



ADVANTAGES AND DRAWBACKS

○ Advantages

- Advantages of being model based (fast labeling, etc)
- Interpretable (depends on operators)
- Can be used independently of application domain
- Expert's knowledge can be built in through operators

○ Disadvantages

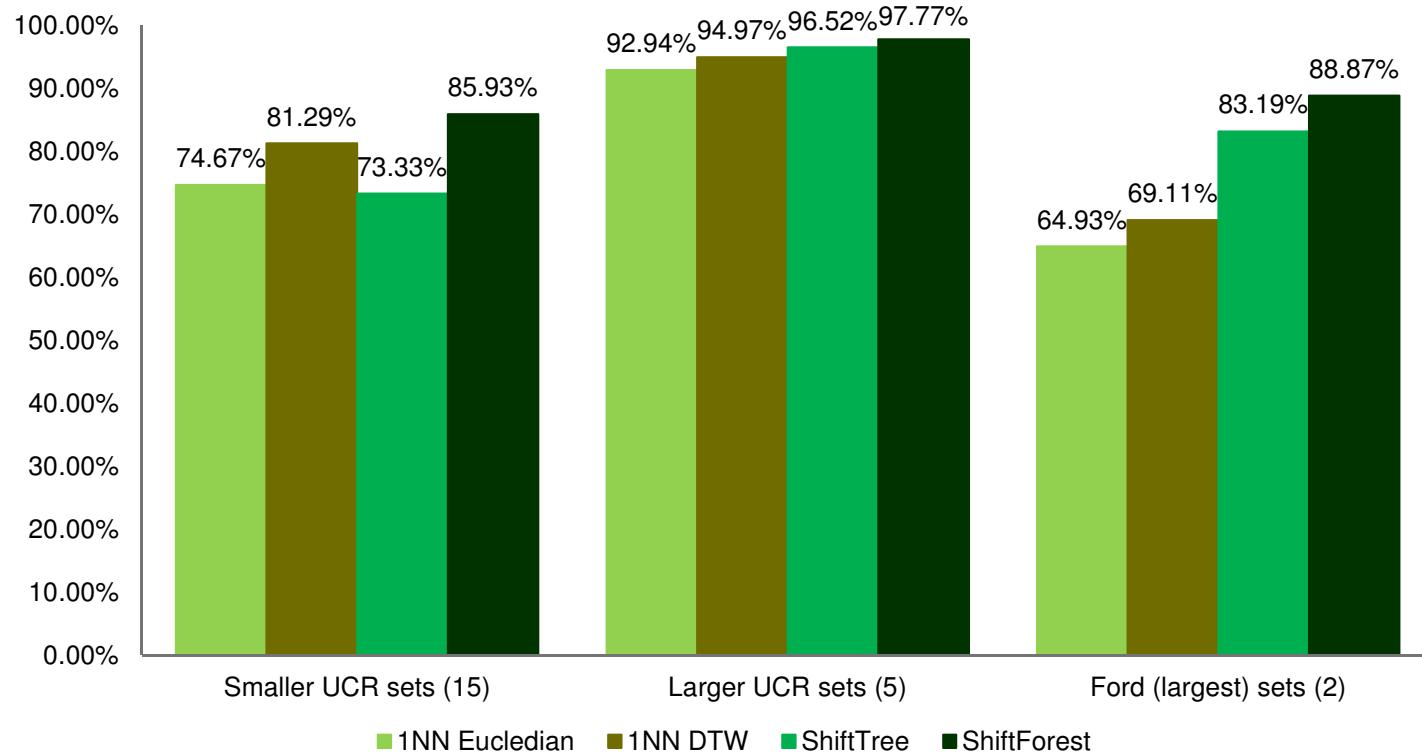
- Optimization of the operators is not trivial
- Learning may take a long time when too many operators used
- Disadvantages of the model based methods (larger training set required, etc)

SHIFTFOREST: COMBINING MULTIPLE MODELS

- Combining models enhances accuracy
- Boosting
 - Some issues on smaller datasets
- The „XV” method
 - Splitting training set (random splits)
 - Building model on the first part, evaluating on the second
 - Model weight: the measured accuracy

SHIFTFOREST RESULTS

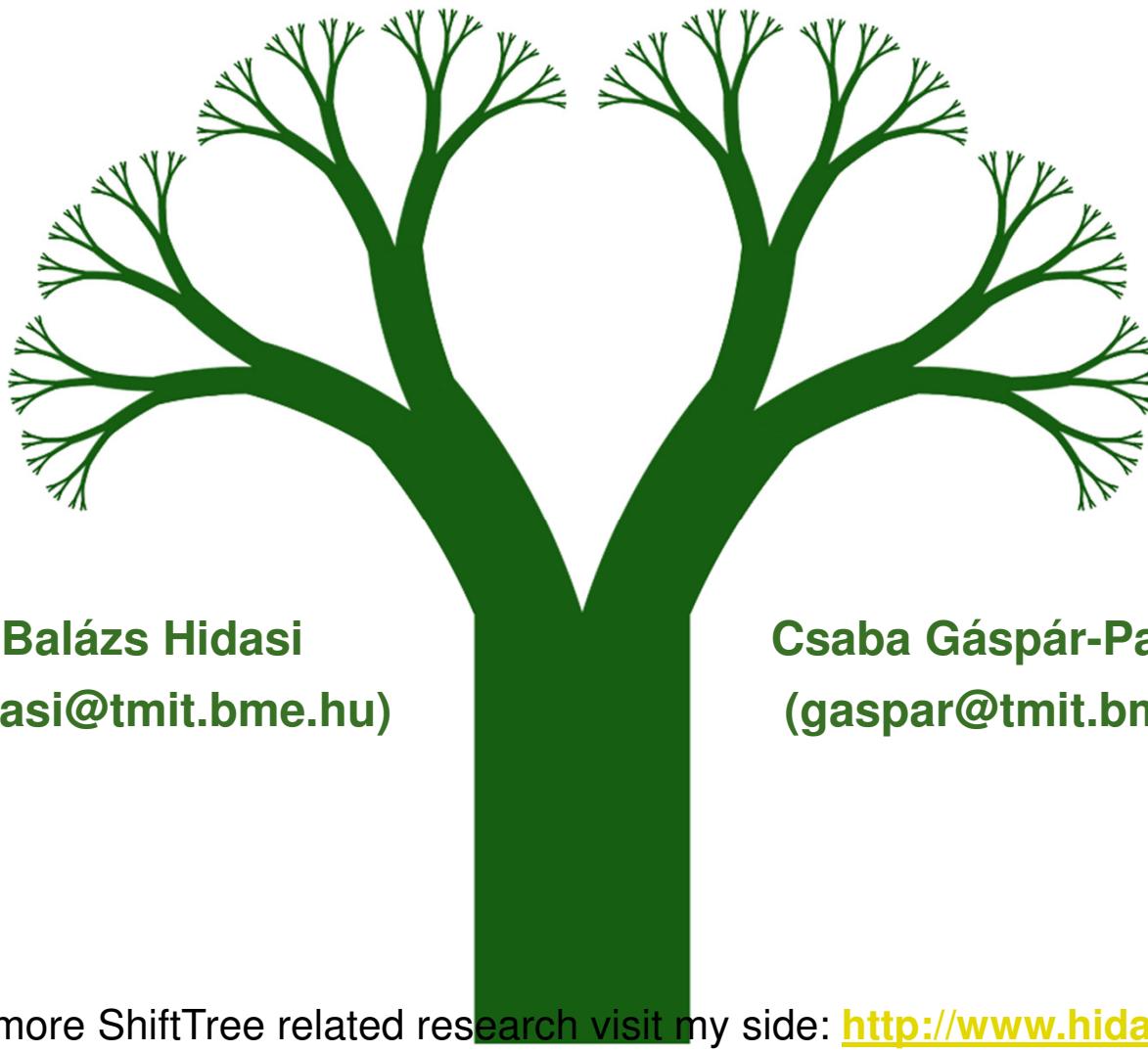
- Accuracy increases
- Interpretability is often lost
 - May the intersection of the trees can be interpreted



CONCLUSION

- Novel model-based algorithm
- Uses cursors and operators
 - Cursor movement
 - Attribute computation
- Sequence of simple operators as the model
 - Decision tree
- Base of a whole algorithm family

THANK YOU FOR YOUR ATTENTION!



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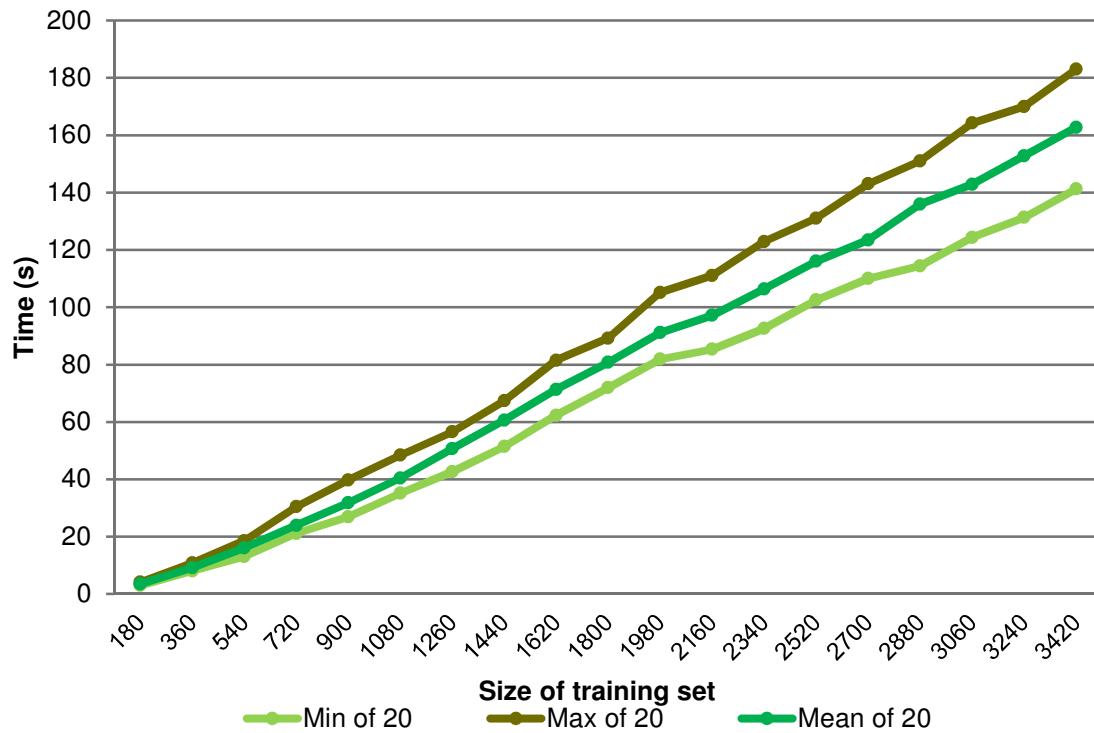
For more ShiftTree related research visit my side: <http://www.hidasi.eu>

TIME OF MODEL BUILDING, SCALABILITY

- $O(N^* \log(N))$ per node (ordering)

- Time of model building
 - Depends on tree structure
 - Acceptable

- Scales linearly
 - Experiments



LEARNING THE MODEL

Defined operators

ESO	ESONextMax	To the next local maxima
	ESONext100	Step forward 100
	ESOMax	To the global maxima
CBO	CBOSimple	Value at cursor position

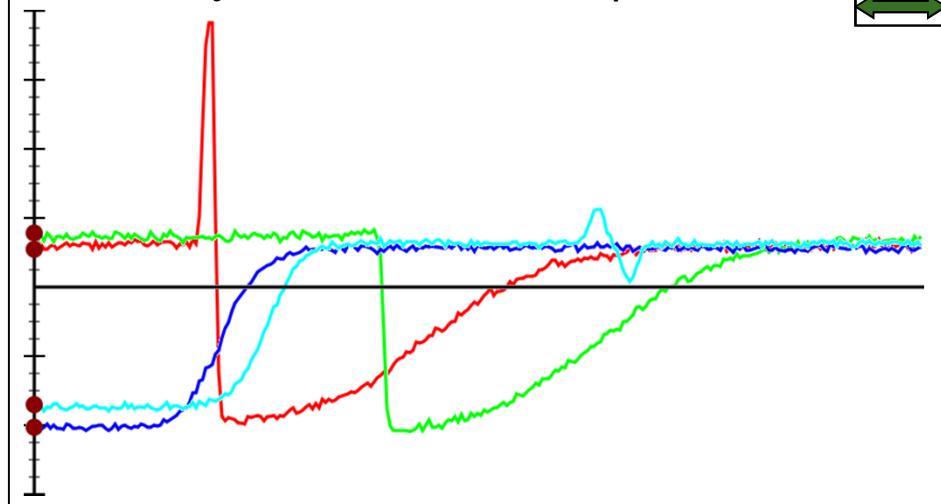
ShiftTree



Best split in node (so far)

ESO:	-
CBO:	-
Threshold:	-

EyeShifter – Cursor position



ConditionBuilder - Ordering



Dynamic attribute selection

Best threshold by current dynamic attribute:	-
Score of the best split by current dyn. attribute :	Inf
Best score in the node (so far)	Inf
Best ordering:	

LEARNING THE MODEL

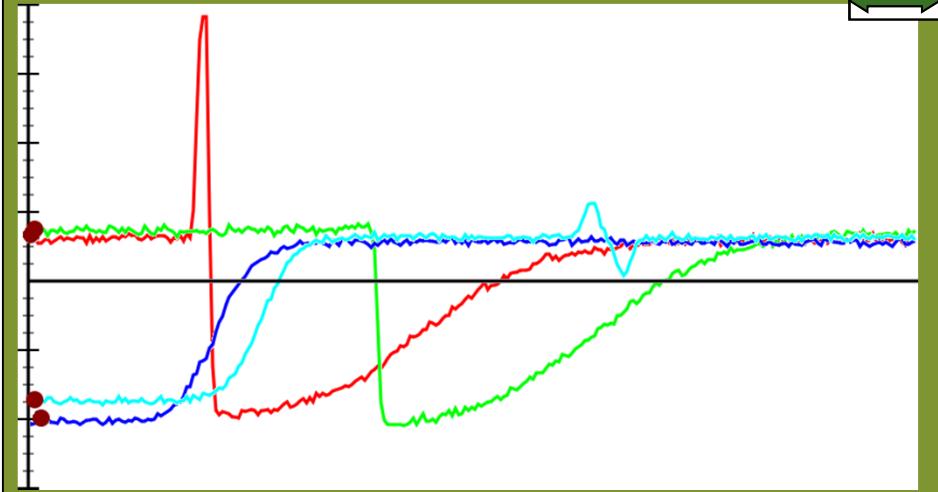
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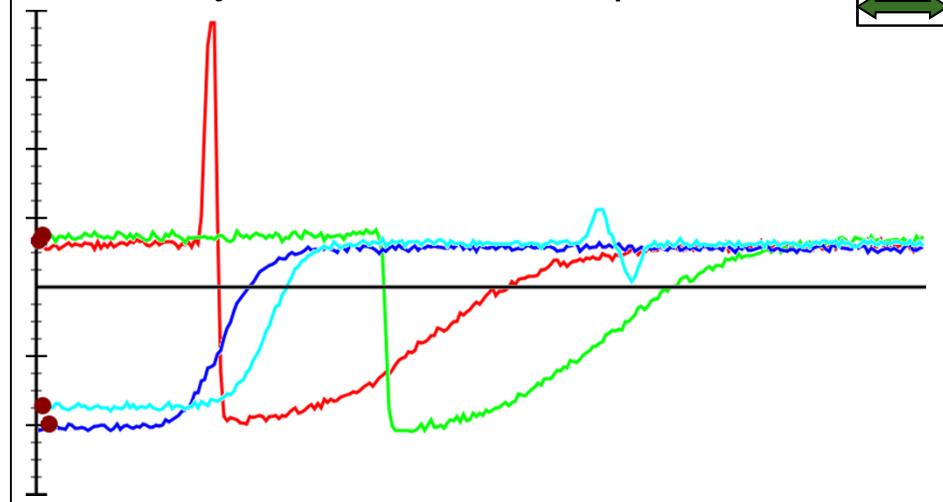
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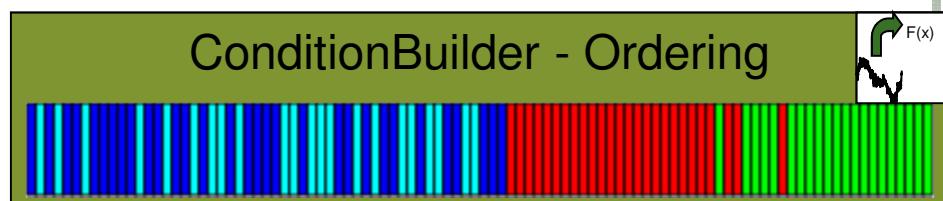
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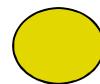
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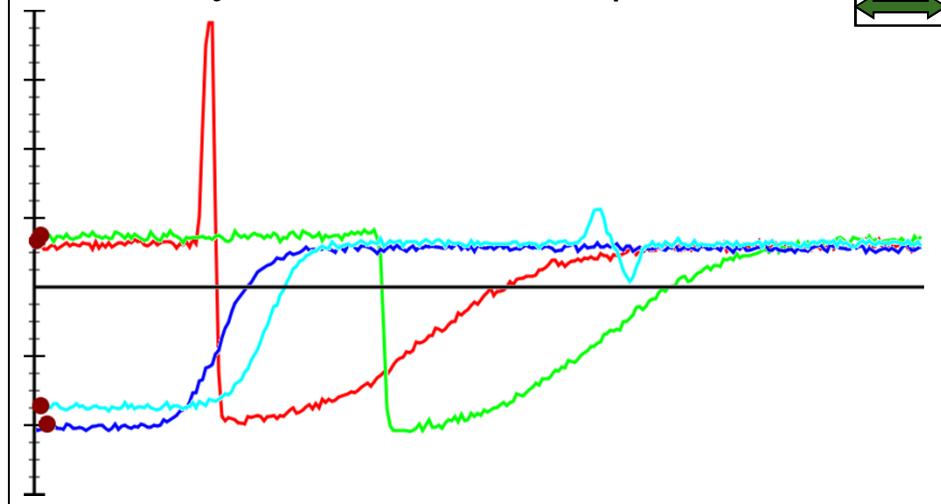
ShiftTree



Best split in node (so far)

ESO:	-
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Threshold:	-

EyeShifter – Cursor position



ConditionBuilder - Ordering



Dynamic attribute selection

Best threshold by current dynamic attribute:	-0,332858
Score of the best split by current dyn. attribute :	0,985078
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Best ordering:	

LEARNING THE MODEL

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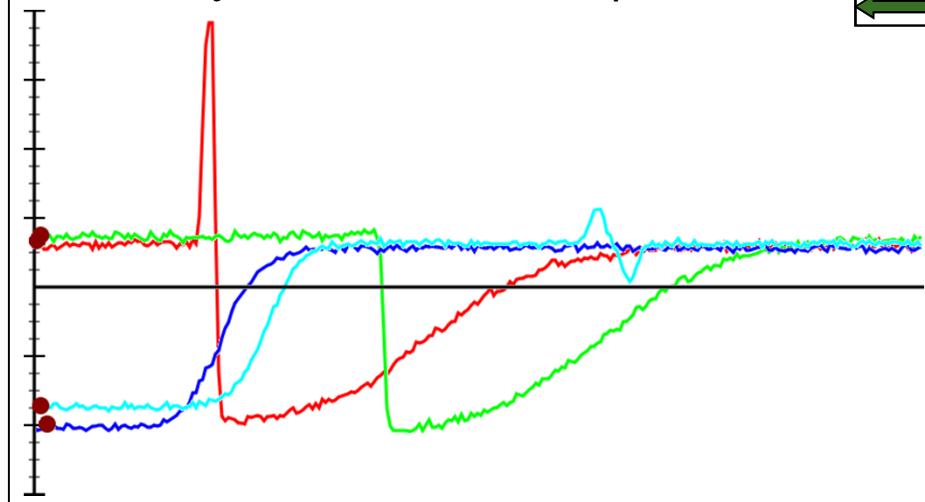
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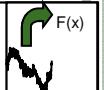
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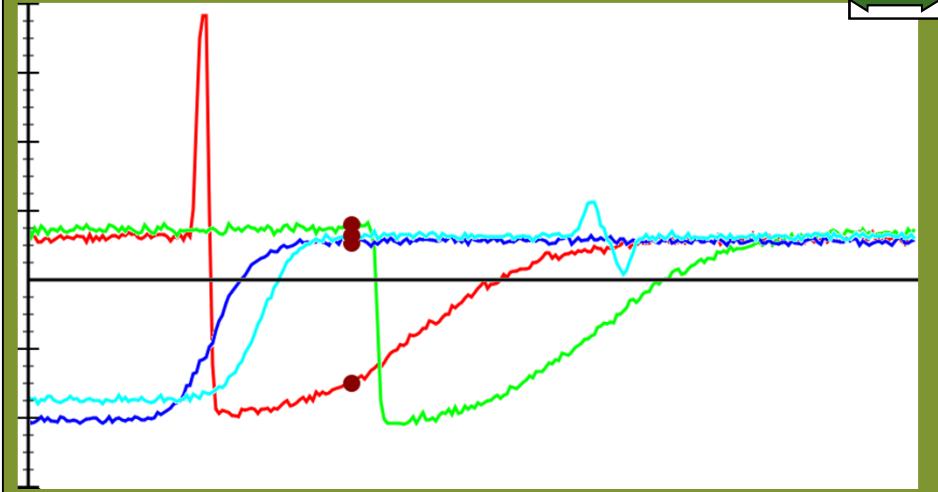
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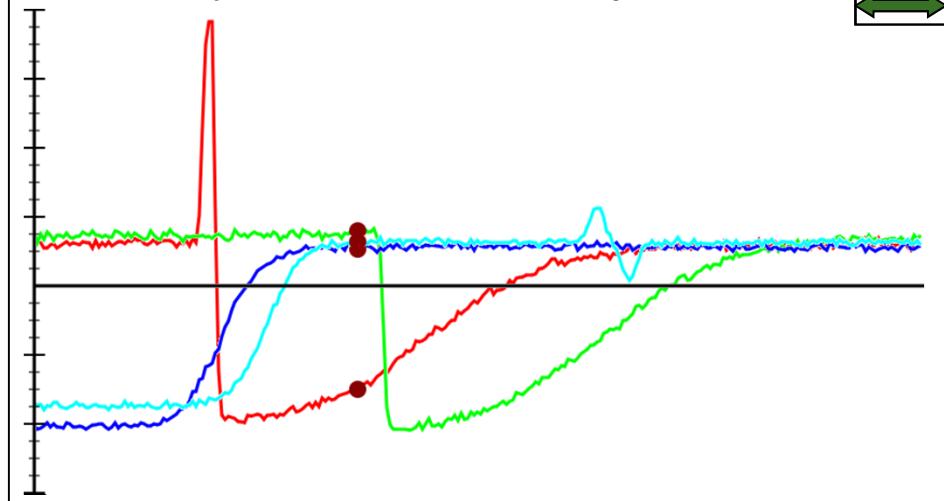
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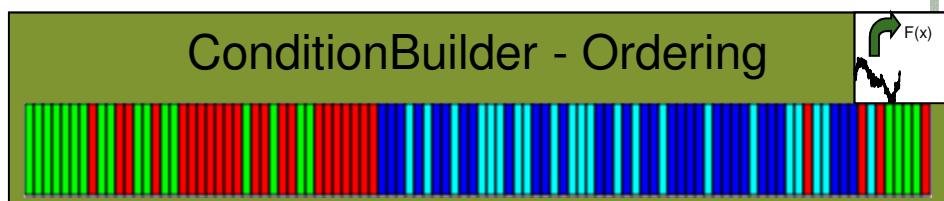
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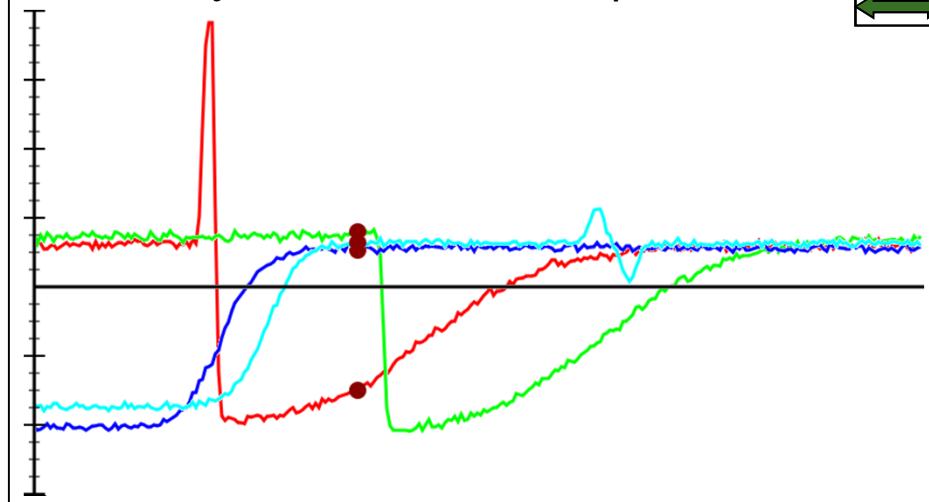
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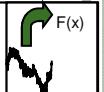
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EyeShifter – Cursor position



ConditionBuilder - Ordering



Dynamic attribute selection



Best threshold by current dynamic attribute:	-1,16155
Score of the best split by current dyn. attribute :	1,32624
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LEARNING THE MODEL

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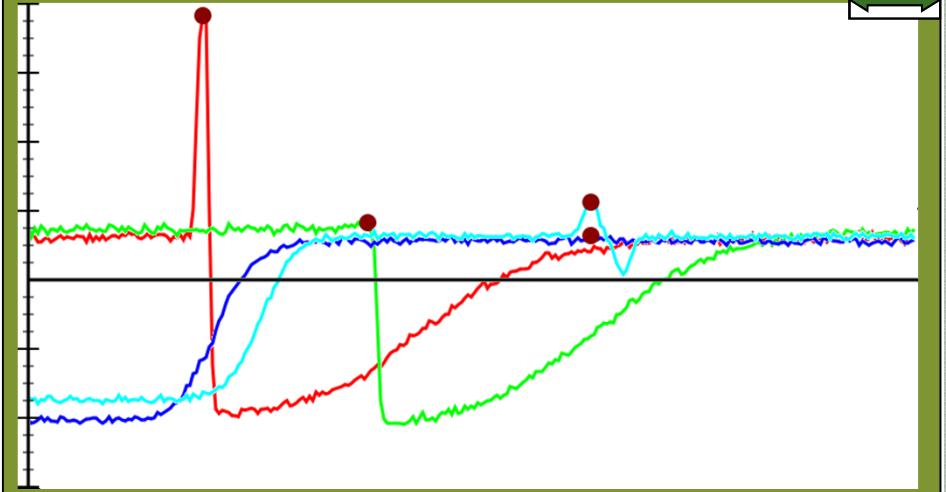
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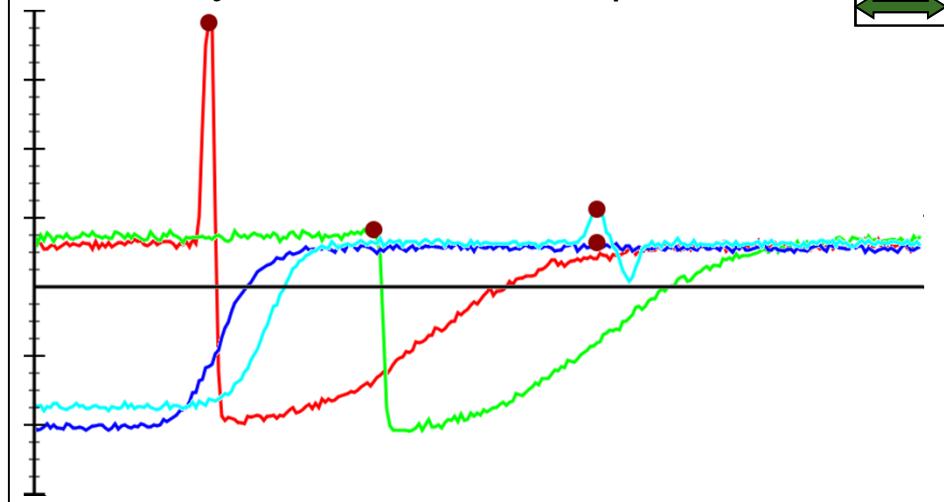
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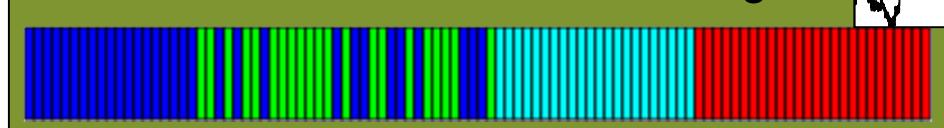
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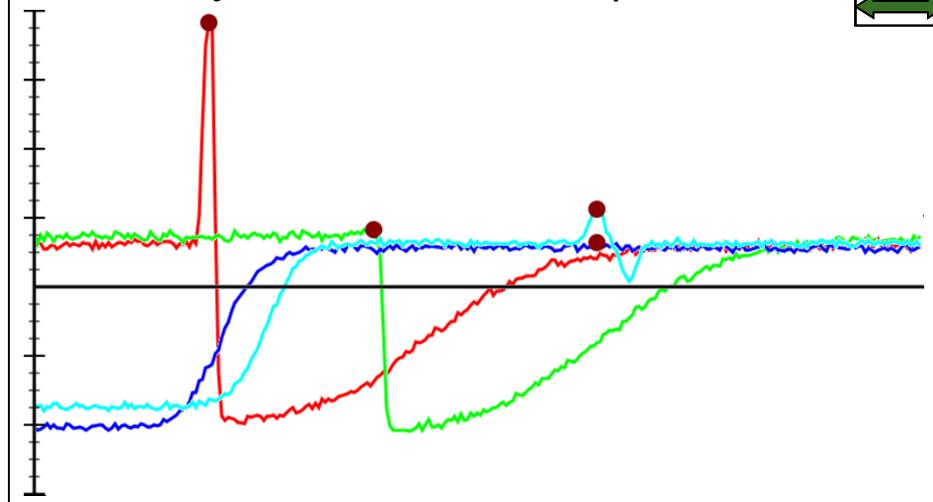
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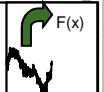
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Best threshold by current dynamic attribute:	1,02775
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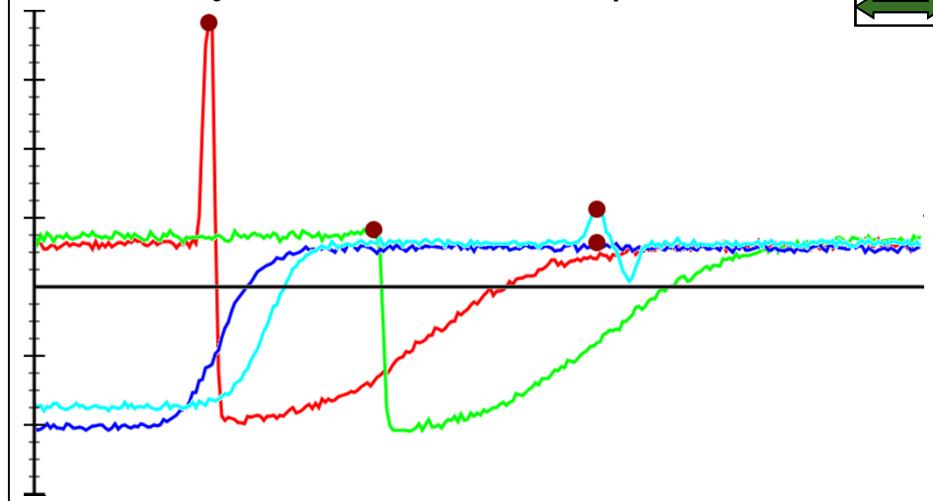
ShiftTree



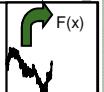
Best split in node (so far)

ESO:	ESOMax
CBO:	CBOSimple
Threshold:	1,02775

EyeShifter – Cursor position



ConditionBuilder - Ordering



Dynamic attribute selection



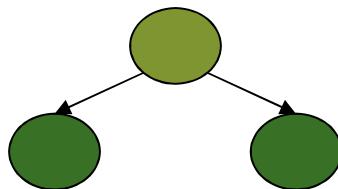
Best threshold by current dynamic attribute:	1,02775
Score of the best split by current dyn. attribute :	0,983634
Best score in the node (so far)	0,983634
Best ordering:	

LEARNING THE MODEL

Defined operators

ESO	ESONextMax	To the next local maxima
	ESONext100	Step forward 100
	ESOMax	To the global maxima
CBO	CBOSimple	Value at cursor position

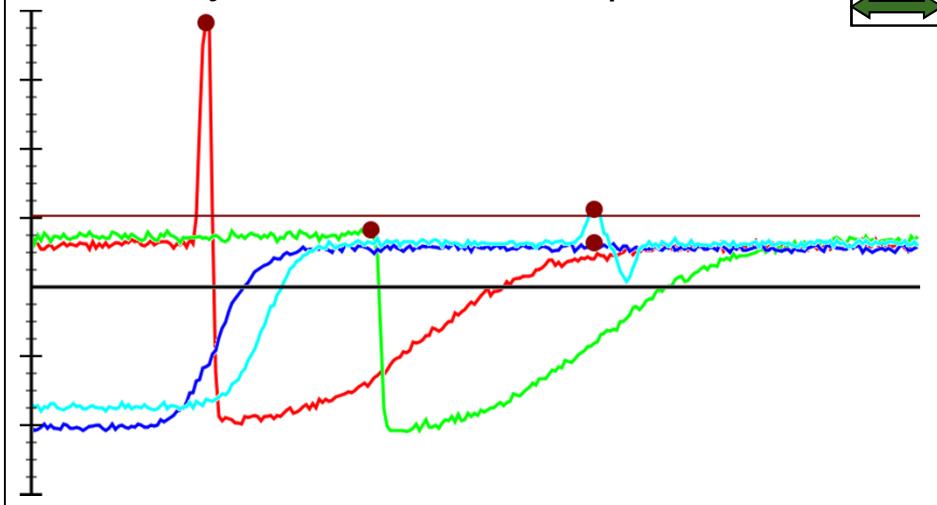
ShiftTree



Best split in node (so far)

ESO:	-
CBO:	-
Threshold:	-

EyeShifter – Cursor position



ConditionBuilder - Ordering



Dynamic attribute selection

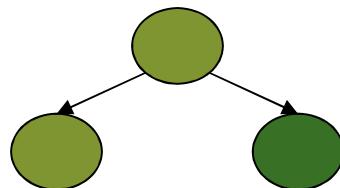
Best threshold by current dynamic attribute:	1,02775
Score of the best split by current dyn. attribute :	0,983634
Best score in the node (so far)	0,983634
Best ordering:	

LEARNING THE MODEL

Defined operators

ESO	ESONextMax	To the next local maxima
	ESONext100	Step forward 100
	ESOMax	To the global maxima
CBO	CBOSimple	Value at cursor position

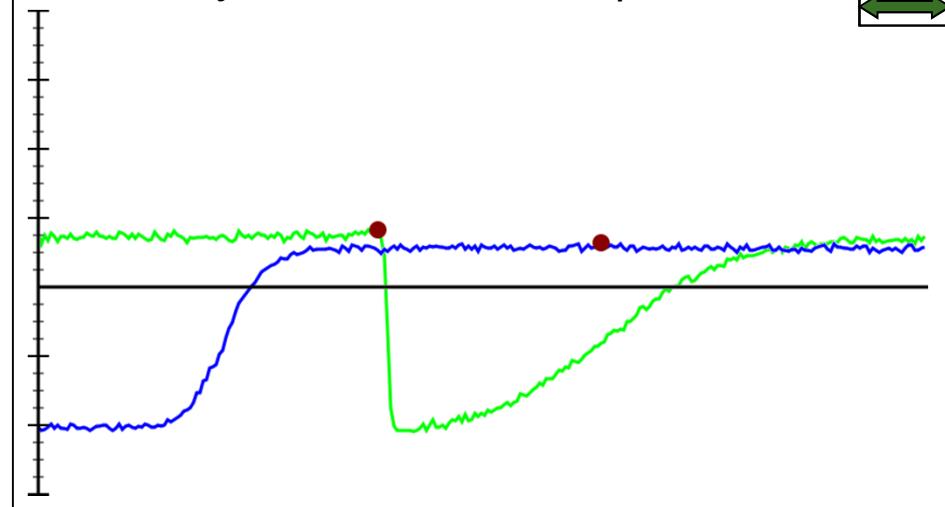
ShiftTree



Best split in node (so far)

ESO:	-
CBO:	-
Threshold:	-

EyeShifter – Cursor position



ConditionBuilder - Ordering



Dynamic attribute selection

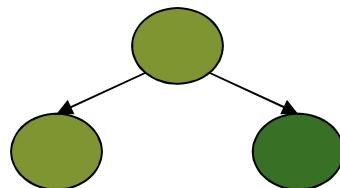
Best threshold by current dynamic attribute:	-
Score of the best split by current dyn. attribute :	Inf
Best score in the node (so far)	Inf
Best ordering:	

LEARNING THE MODEL

Defined operators

ESO	ESONextMax	To the next local maxima
	ESONext100	Step forward 100
	ESOMax	To the global maxima
CBO	CBOSimple	Value at cursor position

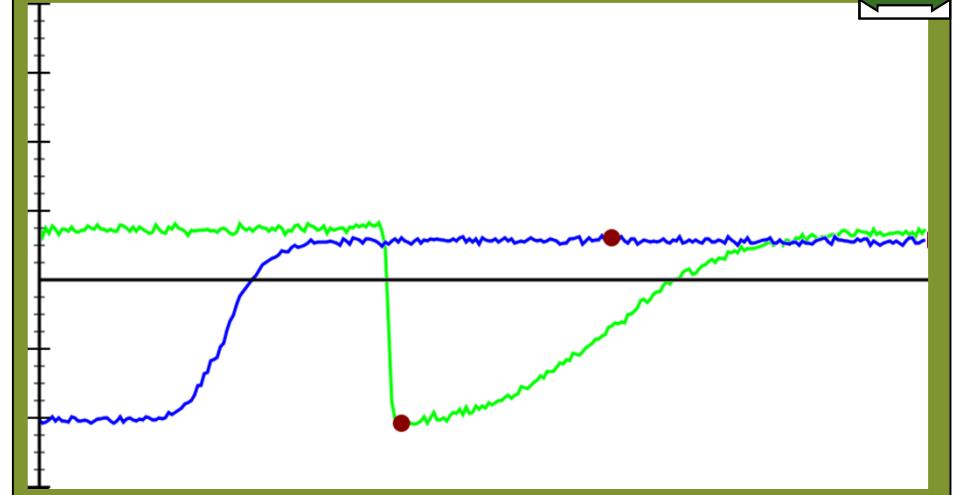
ShiftTree



Best split in node (so far)

ESO:	-
CBO:	-
Threshold:	-

EyeShifter – Cursor position



ConditionBuilder - Ordering



Dynamic attribute selection

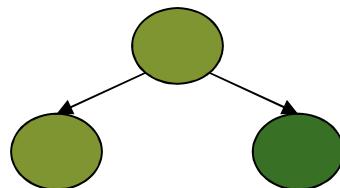
Best threshold by current dynamic attribute:	-
Score of the best split by current dyn. attribute :	Inf
Best score in the node (so far)	Inf
Best ordering:	

LEARNING THE MODEL

Defined operators

ESO	ESONextMax	To the next local maxima
	ESONext100	Step forward 100
	ESOMax	To the global maxima
CBO	CBOSimple	Value at cursor position

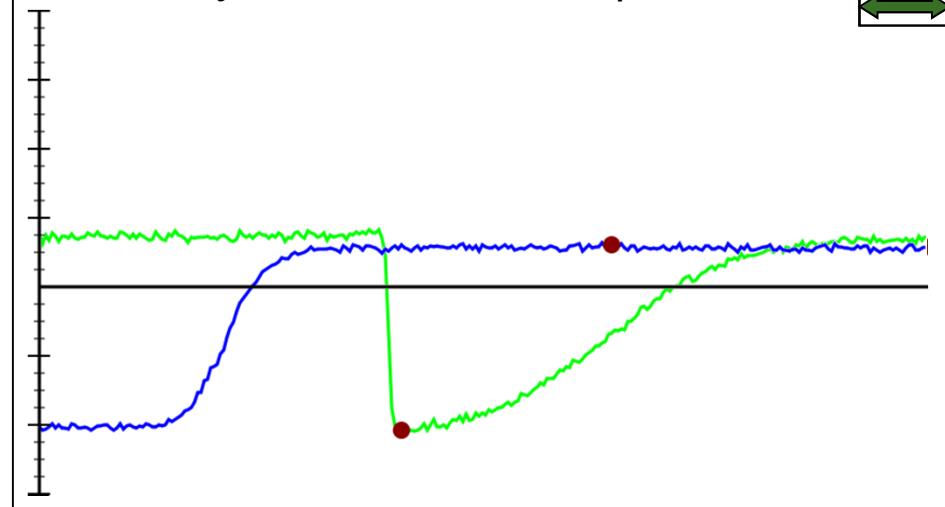
ShiftTree



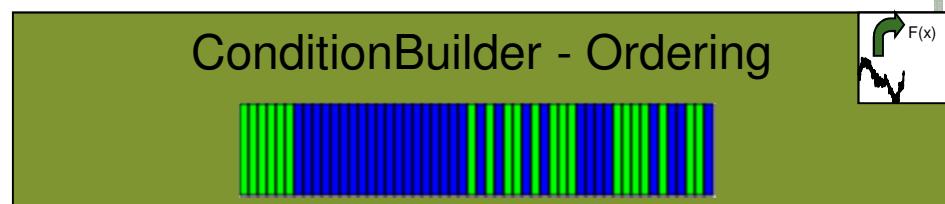
Best split in node (so far)

ESO:	-
CBO:	-
Threshold:	-

EyeShifter – Cursor position



ConditionBuilder - Ordering



Dynamic attribute selection

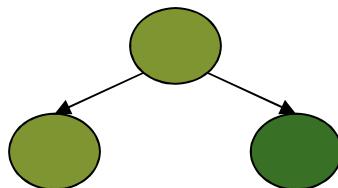
Best threshold by current dynamic attribute:	-
Score of the best split by current dyn. attribute :	Inf
Best score in the node (so far)	Inf
Best ordering:	

LEARNING THE MODEL

Defined operators

ESO	ESONextMax	To the next local maxima
	ESONext100	Step forward 100
	ESOMax	To the global maxima
CBO	CBOSimple	Value at cursor position

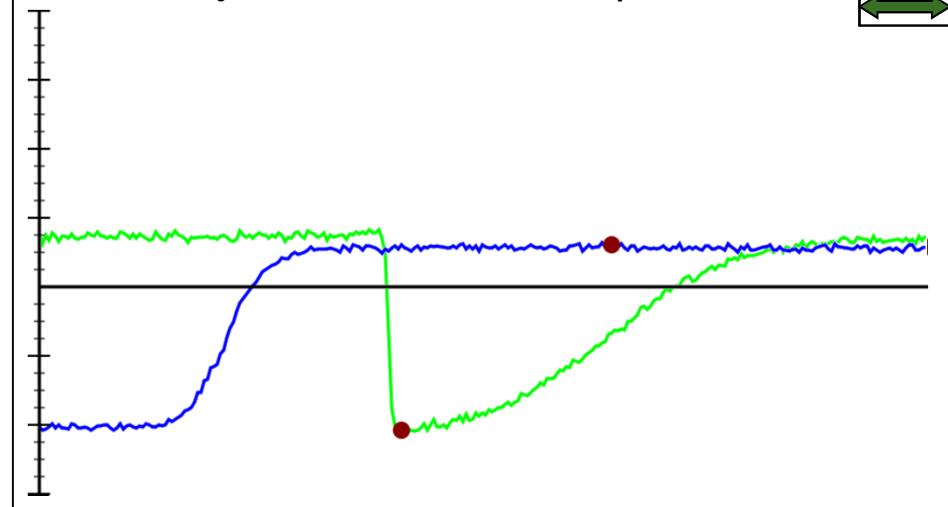
ShiftTree



Best split in node (so far)

ESO:	-
CBO:	-
Threshold:	-

EyeShifter – Cursor position



ConditionBuilder - Ordering



Dynamic attribute selection

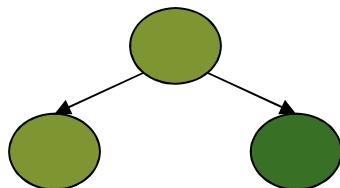
Best threshold by current dynamic attribute:	-0,739969
Score of the best split by current dyn. attribute :	0,805777
Best score in the node (so far)	0,805777
Best ordering:	

LEARNING THE MODEL

Defined operators

ESO	ESONextMax	To the next local maxima
	ESONext100	Step forward 100
	ESOMax	To the global maxima
CBO	CBOSimple	Value at cursor position

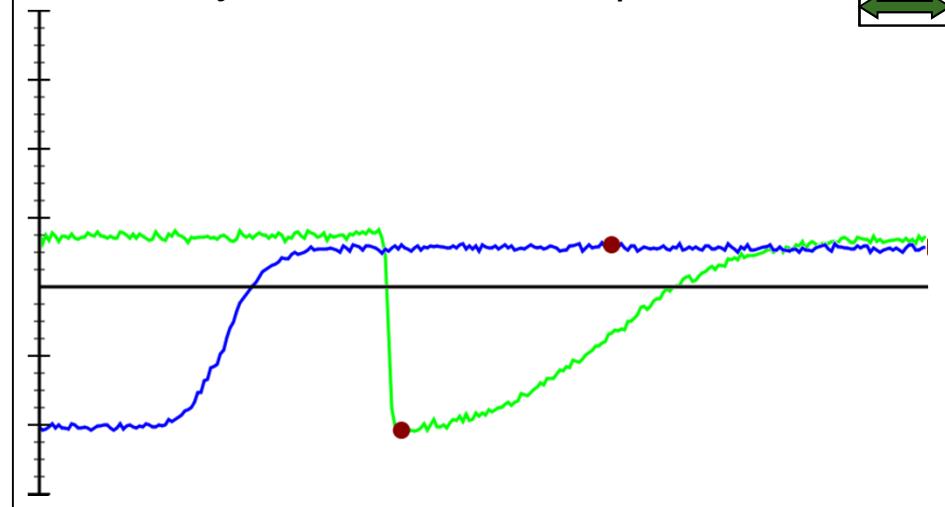
ShiftTree



Best split in node (so far)

ESO:	ESONextMax
CBO:	CBOSimple
Threshold:	-0,739969

EyeShifter – Cursor position



ConditionBuilder - Ordering



Dynamic attribute selection

Best threshold by current dynamic attribute:	-0,739969
Score of the best split by current dyn. attribute :	0,805777
Best score in the node (so far)	0,805777
Best ordering:	

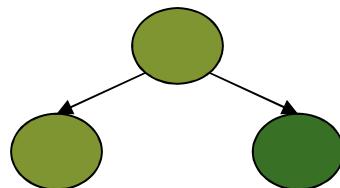


LEARNING THE MODEL

Defined operators

ESO	ESONextMax	To the next local maxima
	ESONext100	Step forward 100
	ESOMax	To the global maxima
CBO	CBOSimple	Value at cursor position

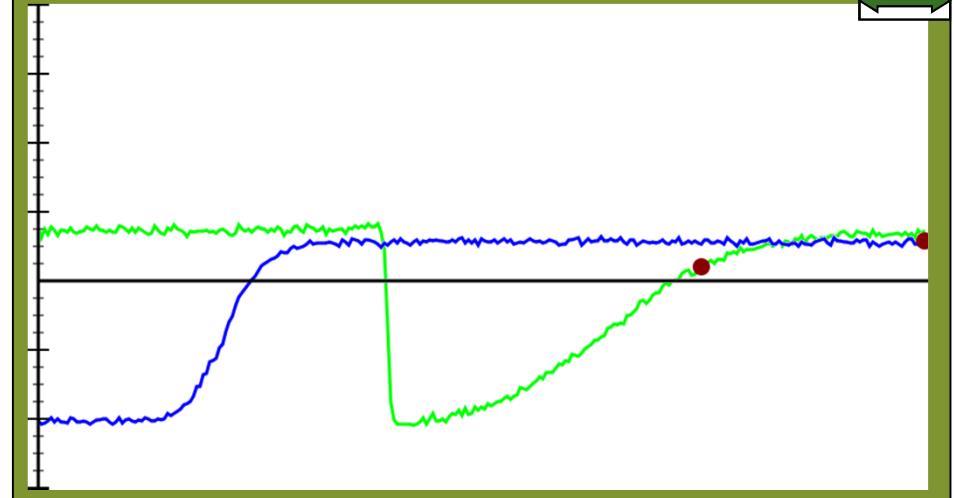
ShiftTree



Best split in node (so far)

ESO:	ESONextMax
CBO:	CBOSimple
Threshold:	-0,739969

EyeShifter – Cursor position



ConditionBuilder - Ordering



Dynamic attribute selection

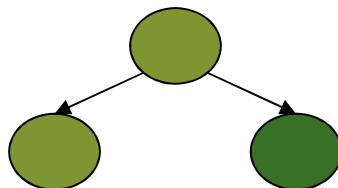
Best threshold by current dynamic attribute:	-0,739969
Score of the best split by current dyn. attribute :	0,805777
Best score in the node (so far)	0,805777
Best ordering:	

LEARNING THE MODEL

Defined operators

ESO	ESONextMax	To the next local maxima
	ESONext100	Step forward 100
	ESOMax	To the global maxima
CBO	CBOSimple	Value at cursor position

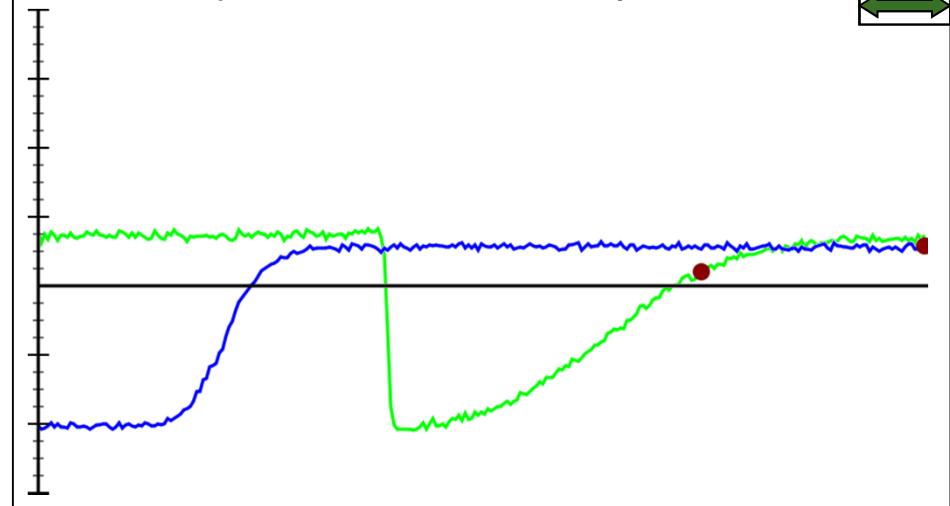
ShiftTree



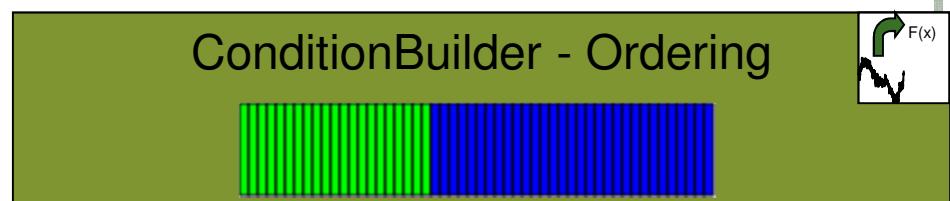
Best split in node (so far)

ESO:	ESONextMax
CBO:	CBOSimple
Threshold:	-0,739969

EyeShifter – Cursor position



ConditionBuilder - Ordering



Dynamic attribute selection

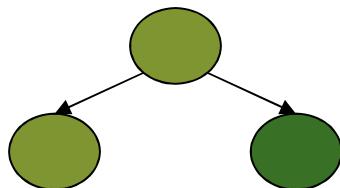
Best threshold by current dynamic attribute:	-0,739969
Score of the best split by current dyn. attribute :	0,805777
Best score in the node (so far)	0,805777
Best ordering:	

LEARNING THE MODEL

Defined operators

ESO	ESONextMax	To the next local maxima
	ESONext100	Step forward 100
	ESOMax	To the global maxima
CBO	CBOSimple	Value at cursor position

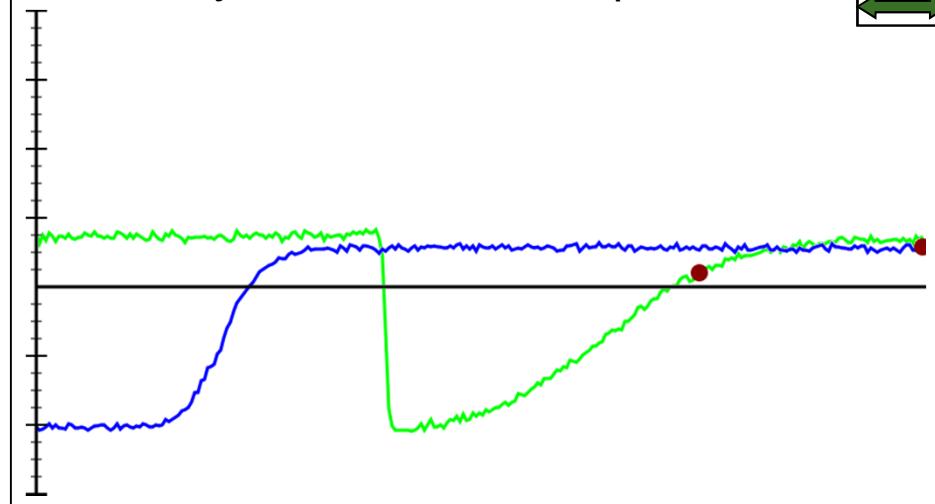
ShiftTree



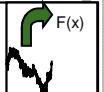
Best split in node (so far)

ESO:	ESONextMax
CBO:	CBOSimple
Threshold:	-0,739969

EyeShifter – Cursor position



ConditionBuilder - Ordering



Dynamic attribute selection



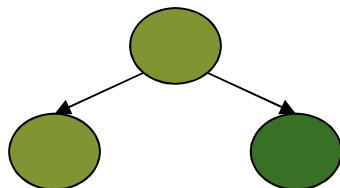
Best threshold by current dynamic attribute:	0,390093
Score of the best split by current dyn. attribute :	0
Best score in the node (so far)	0
Best ordering:	

LEARNING THE MODEL

Defined operators

ESO	ESONextMax	To the next local maxima
	ESONext100	Step forward 100
	ESOMax	To the global maxima
CBO	CBOSimple	Value at cursor position

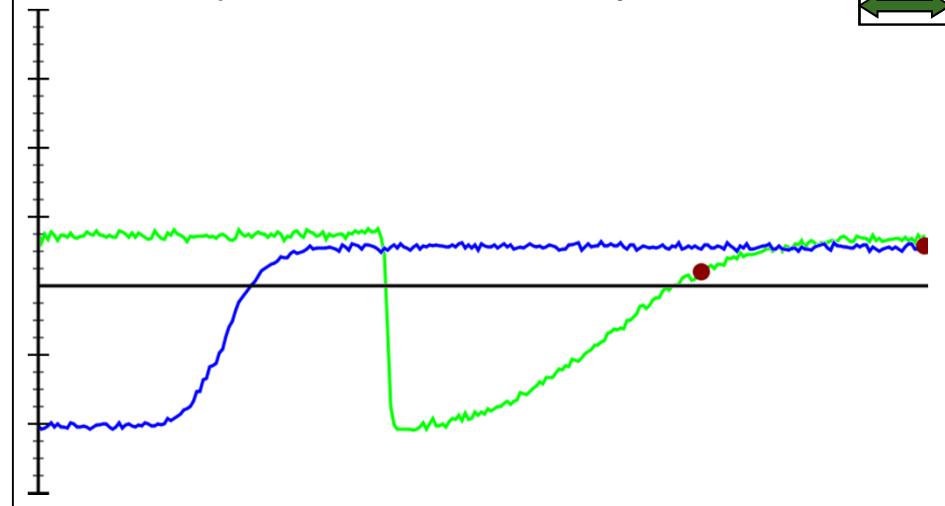
ShiftTree



Best split in node (so far)

ESO:	ESONext100
CBO:	CBOSimple
Threshold:	0,390093

EyeShifter – Cursor position



ConditionBuilder - Ordering



Dynamic attribute selection

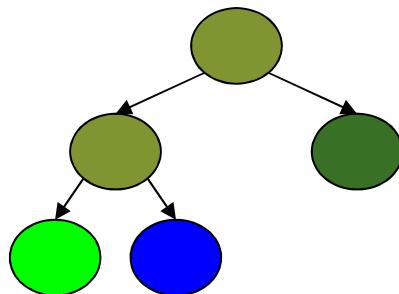
Best threshold by current dynamic attribute:	0,390093
Score of the best split by current dyn. attribute :	0
Best score in the node (so far)	0
Best ordering:	

LEARNING THE MODEL

Defined operators

ESO	ESONextMax	To the next local maxima
	ESONext100	Step forward 100
	ESOMax	To the global maxima
CBO	CBOSimple	Value at cursor position

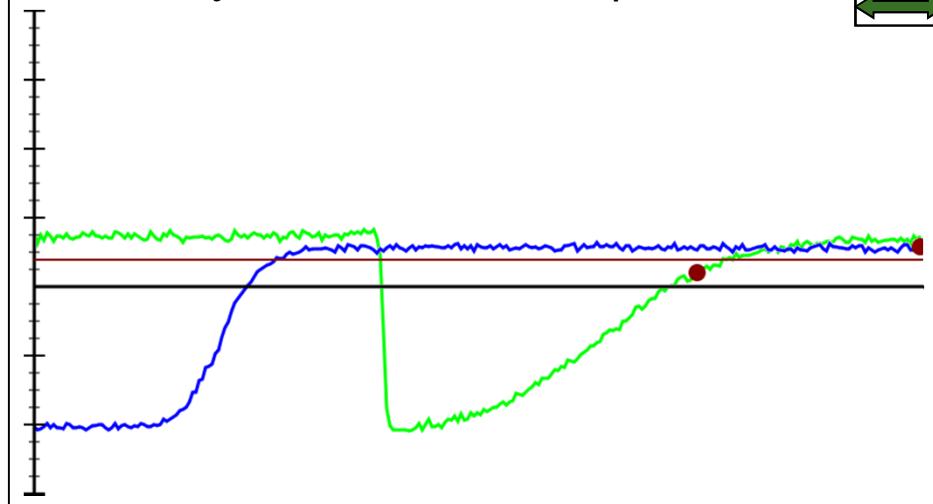
ShiftTree



Best split in node (so far)

ESO:	-
CBO:	-
Threshold:	-

EyeShifter – Cursor position



ConditionBuilder - Ordering



Dynamic attribute selection



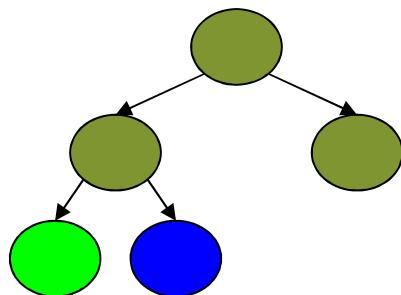
Best threshold by current dynamic attribute:	0,390093
Score of the best split by current dyn. attribute :	0
Best score in the node (so far)	0
Best ordering:	

LEARNING THE MODEL

Defined operators

ESO	ESONextMax	To the next local maxima
	ESONext100	Step forward 100
	ESOMax	To the global maxima
CBO	CBOSimple	Value at cursor position

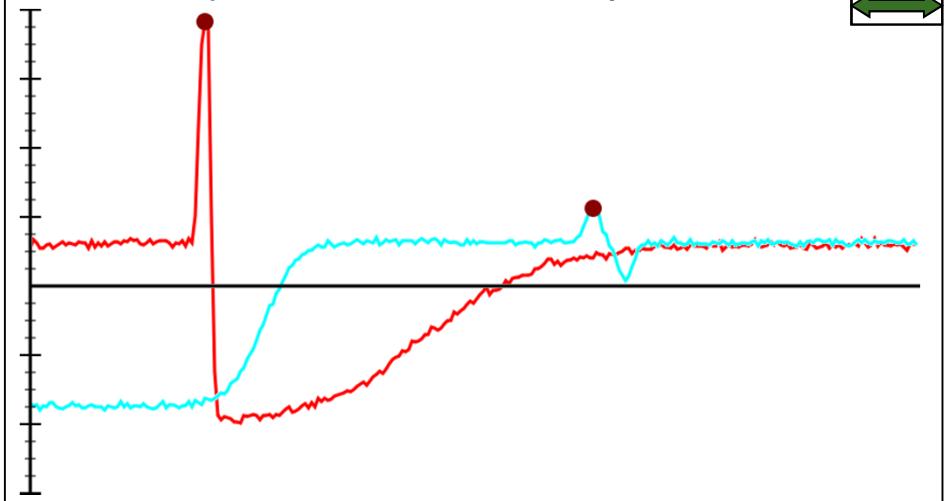
ShiftTree



Best split in node (so far)

ESO:	-
CBO:	-
Threshold:	-

EyeShifter – Cursor position



ConditionBuilder - Ordering



Dynamic attribute selection

Best threshold by current dynamic attribute:	-
Score of the best split by current dyn. attribute :	Inf
Best score in the node (so far)	Inf
Best ordering:	

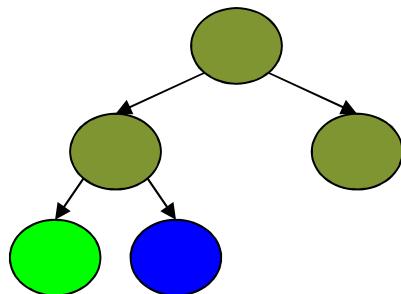


LEARNING THE MODEL

Defined operators

ESO	ESONextMax	To the next local maxima
	ESONext100	Step forward 100
	ESOMax	To the global maxima
CBO	CBOSimple	Value at cursor position

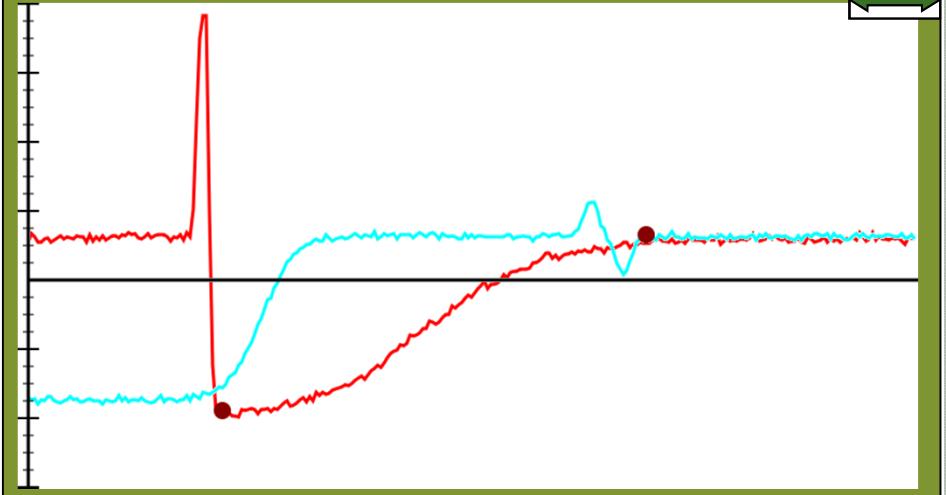
ShiftTree



Best split in node (so far)

ESO:	-
CBO:	-
Threshold:	-

EyeShifter – Cursor position



ConditionBuilder - Ordering



Dynamic attribute selection

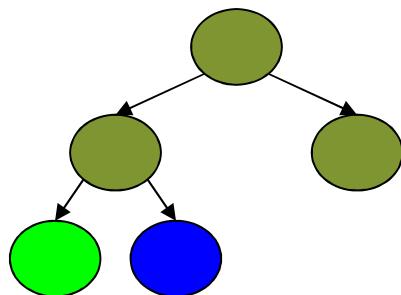
Best threshold by current dynamic attribute:	-
Score of the best split by current dyn. attribute :	Inf
Best score in the node (so far)	Inf
Best ordering:	

LEARNING THE MODEL

Defined operators

ESO	ESONextMax	To the next local maxima
	ESONext100	Step forward 100
	ESOMax	To the global maxima
CBO	CBOSimple	Value at cursor position

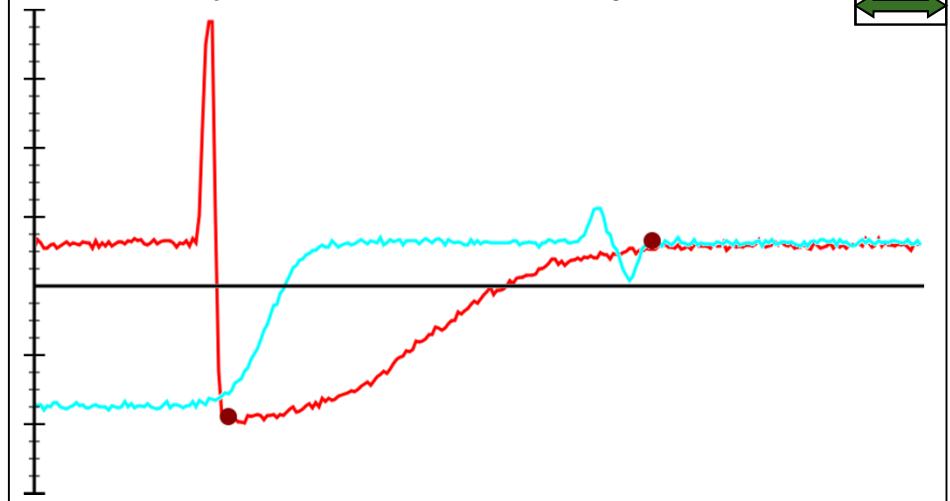
ShiftTree



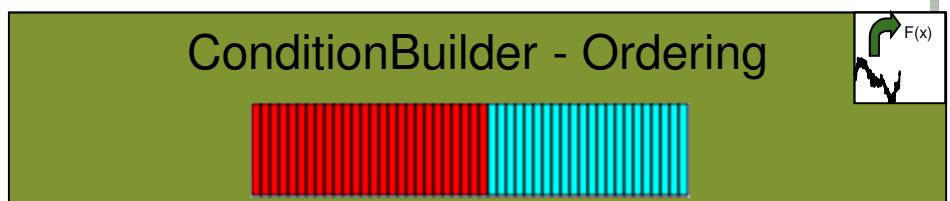
Best split in node (so far)

ESO:	-
CBO:	-
Threshold:	-

EyeShifter – Cursor position



ConditionBuilder - Ordering



Dynamic attribute selection

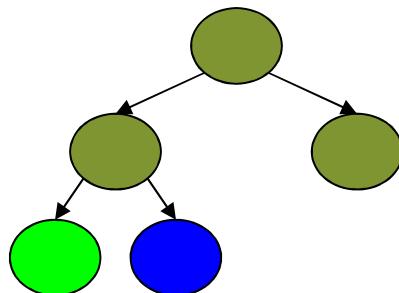
Best threshold by current dynamic attribute:	-
Score of the best split by current dyn. attribute :	Inf
Best score in the node (so far)	Inf
Best ordering:	

LEARNING THE MODEL

Defined operators

ESO	ESONextMax	To the next local maxima
	ESONext100	Step forward 100
	ESOMax	To the global maxima
CBO	CBOSimple	Value at cursor position

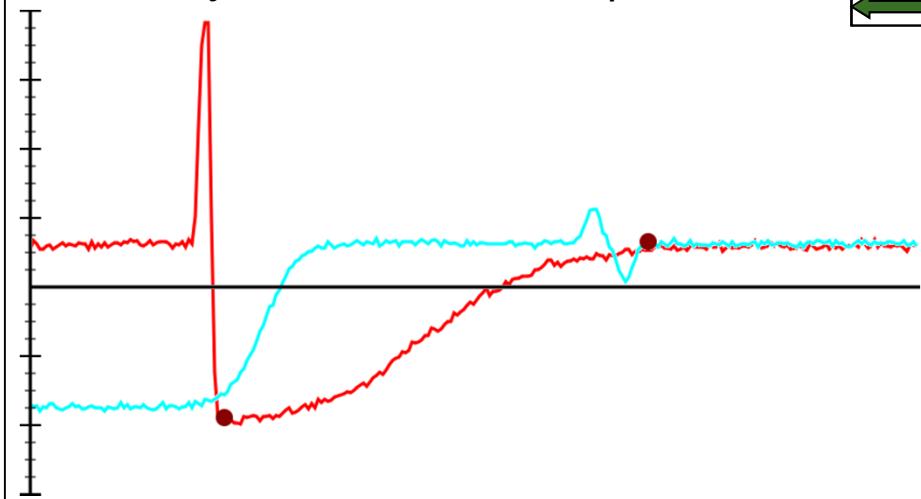
ShiftTree



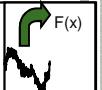
Best split in node (so far)

ESO:	-
CBO:	-
Threshold:	-

EyeShifter – Cursor position



ConditionBuilder - Ordering



Dynamic attribute selection



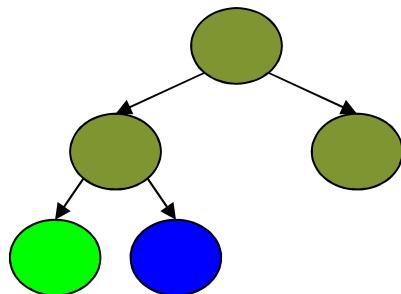
Best threshold by current dynamic attribute:	-0,700739
Score of the best split by current dyn. attribute :	0
Best score in the node (so far):	0
Best ordering:	

LEARNING THE MODEL

Defined operators

ESO	ESONextMax	To the next local maxima
	ESONext100	Step forward 100
	ESOMax	To the global maxima
CBO	CBOSimple	Value at cursor position

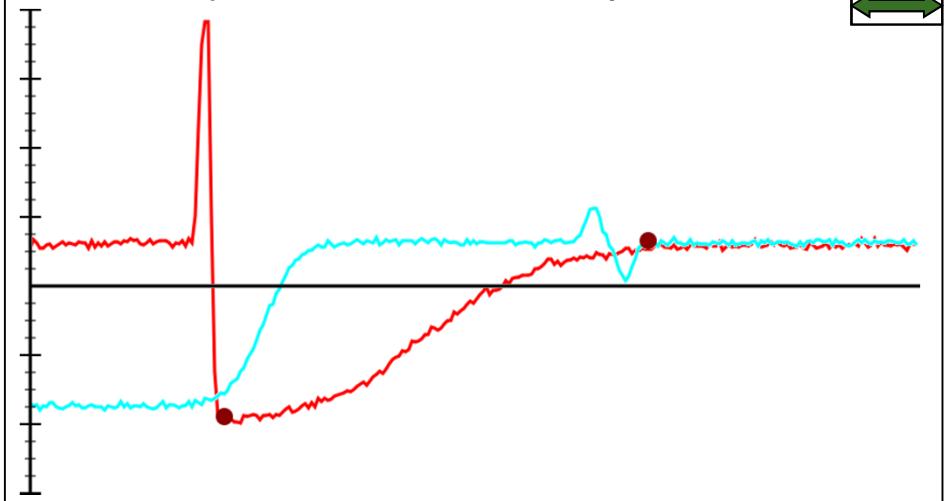
ShiftTree



Best split in node (so far)

ESO:	ESONextMax
CBO:	CBOSimple
Threshold:	-0,700739

EyeShifter – Cursor position



ConditionBuilder - Ordering



Dynamic attribute selection

Best threshold by current dynamic attribute:	-0,700739
Score of the best split by current dyn. attribute :	0
Best score in the node (so far):	0
Best ordering:	

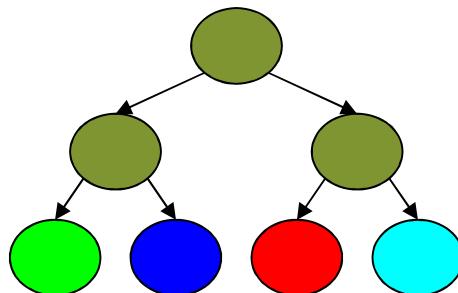


LEARNING THE MODEL

Defined operators

ESO	ESONextMax	To the next local maxima
	ESONext100	Step forward 100
	ESOMax	To the global maxima
CBO	CBOSimple	Value at cursor position

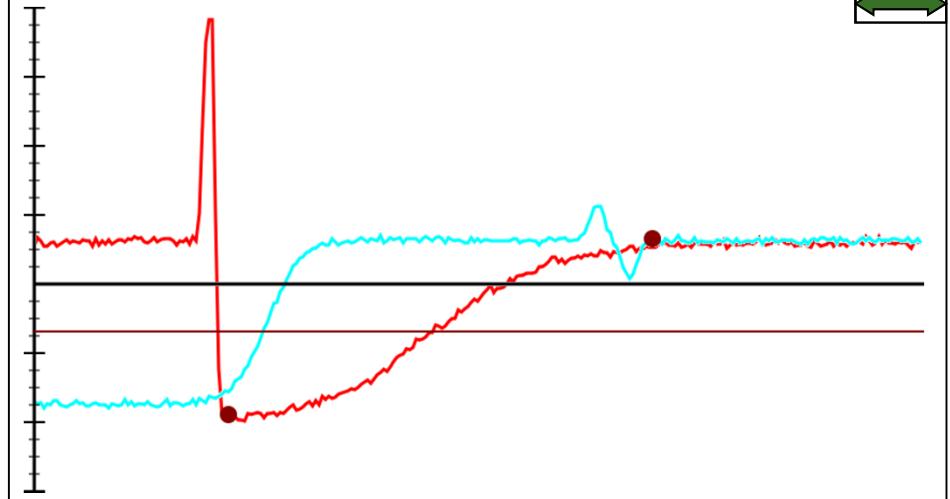
ShiftTree



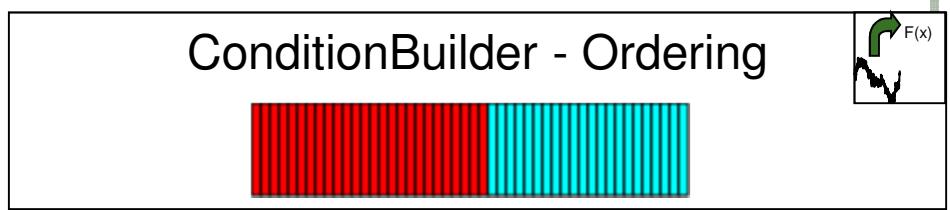
Best split in node (so far)

ESO:	-
CBO:	-
Threshold:	-

EyeShifter – Cursor position



ConditionBuilder - Ordering



Dynamic attribute selection

Best threshold by current dynamic attribute:	-0,700739
Score of the best split by current dyn. attribute :	0
Best score in the node (so far):	0
Best ordering:	