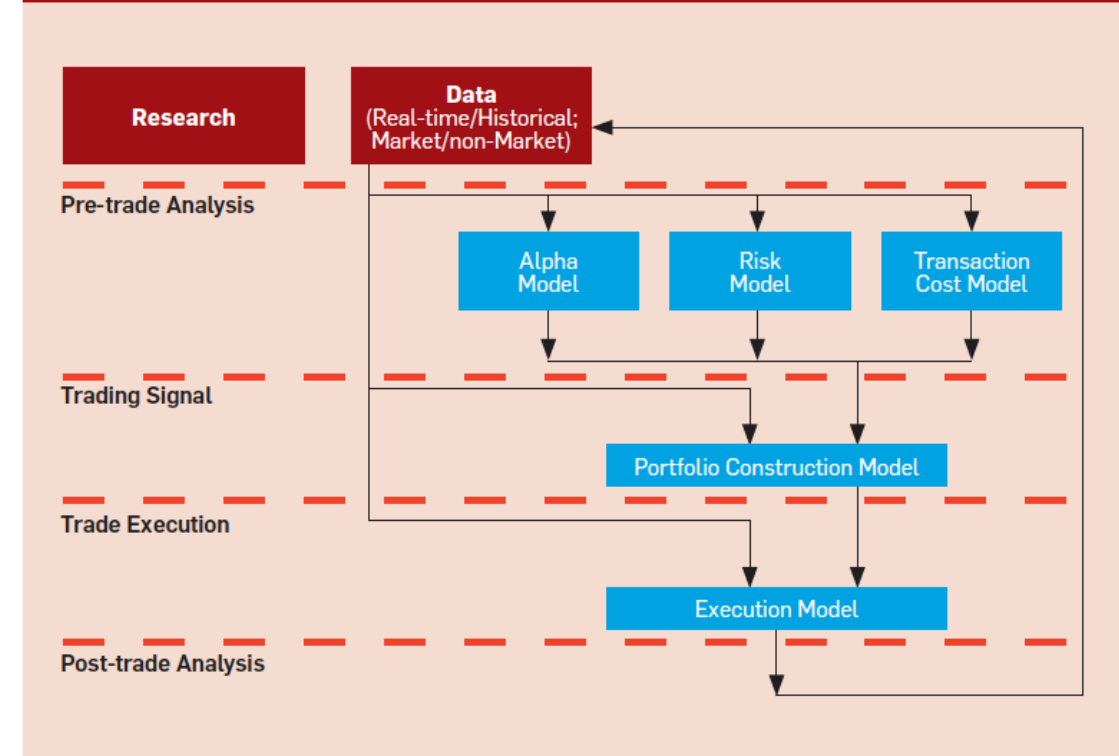


Parallel Heterogeneous Multi-Classfier System for Decision Making in Algorithmic Trading

Algorithmic Trading System



Figure 2. Components of an AT system.



Treleven P., Galas M., Lalchand V.: Algorithmic trading review. Communications of the ACM 56(11), 76-85 (2013).

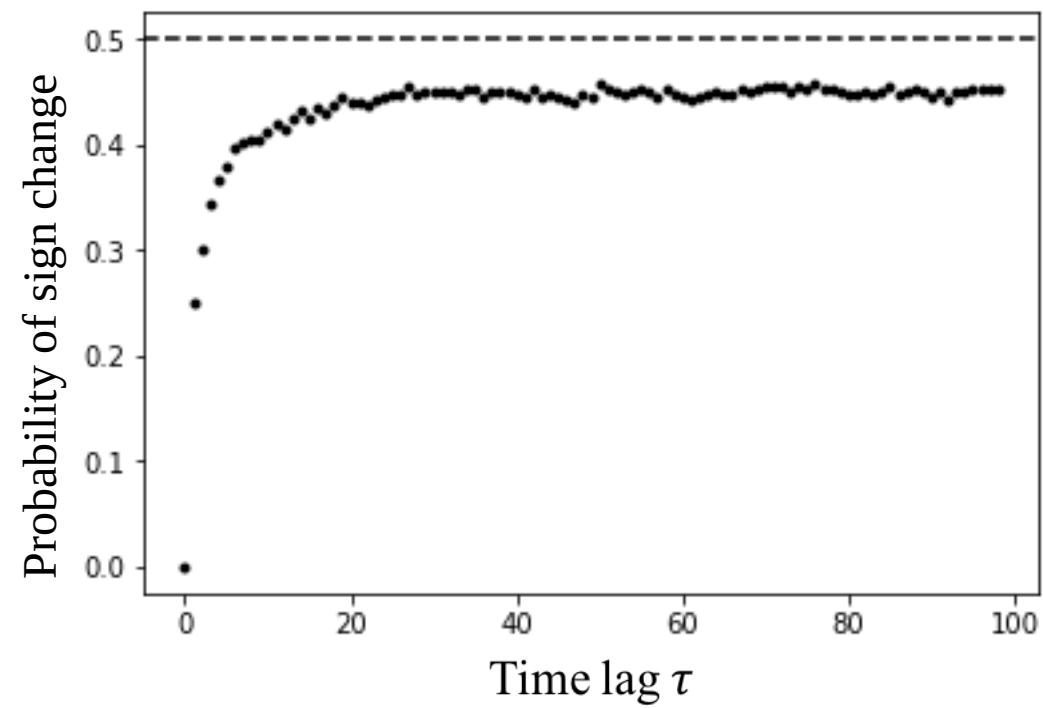
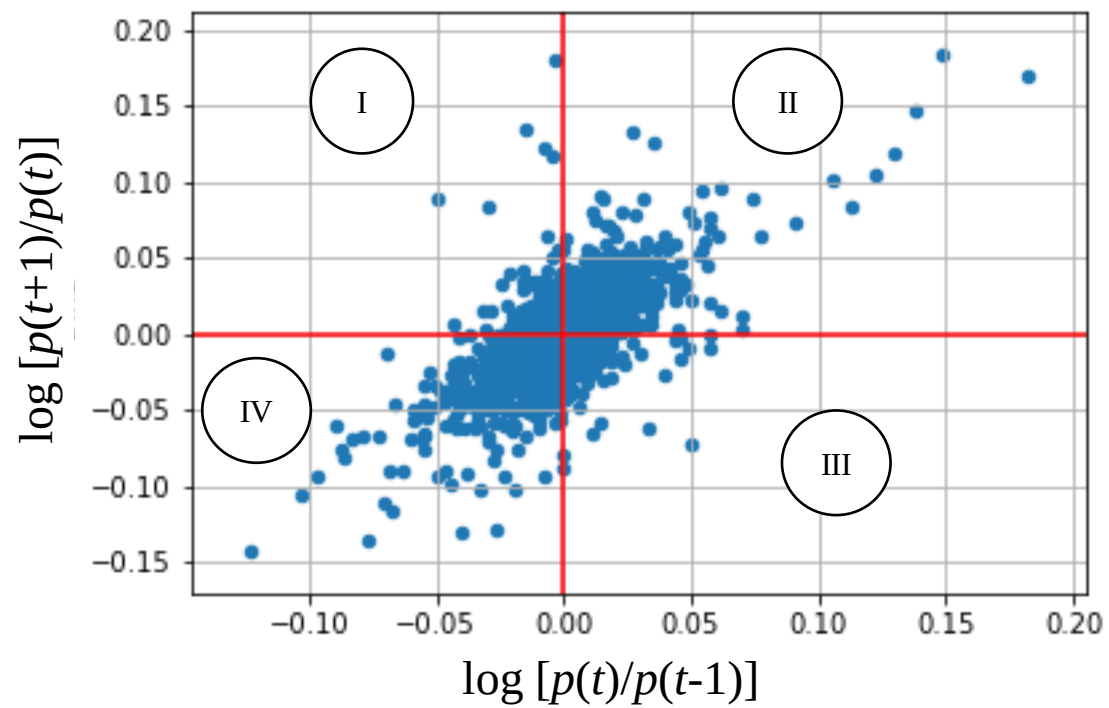
Trading Strategy as a Classification Problem

$$target(t) = \begin{cases} 1, & p(t)/p(t+1) < 1 \\ -1, & p(t)/p(t+1) \geq 1 \end{cases}$$

$p(t)$ and $p(t+1)$ are the ACP's in current (t) and next ($t+1$) trading intervals respectively

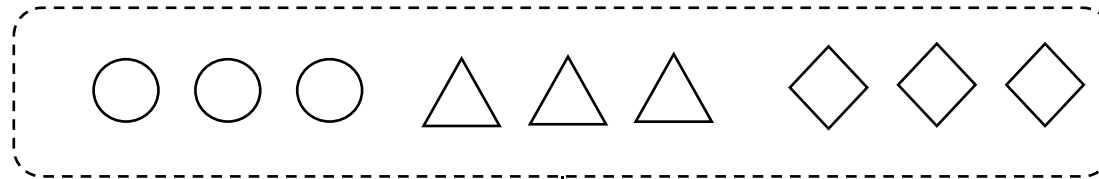
41 features:

- Values of price series (*open*, *close*, *min* and *max* prices, *volume* and *ACP*);
- Technical indicators: $MA_9(t)$, $MA_{50}(t)$, $RSI(t)$, $F(t)$, $S(t)$, $Hist(t)$, $\%K(t)$, $\%D(t)$, $D(t)$;
- Trading signals: $S_{MA}(t)$, $S_{MACD}(t)$, $S_{RSI}(t)$, $S_{stoch}(t)$;
- Sign of $\log[p(t)/p(t-1)]$;
- *Dow-Jones*, *NASDAQ* and *S&P500* indexes and signs of logarithms of their ratios.

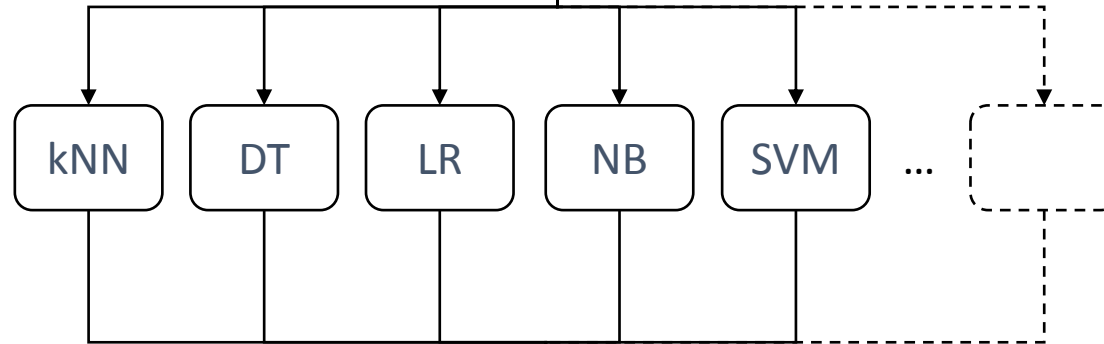


Proposed Model

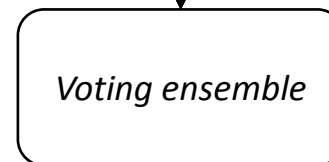
1: Feature engineering



2: Feature selection for each individual classifier

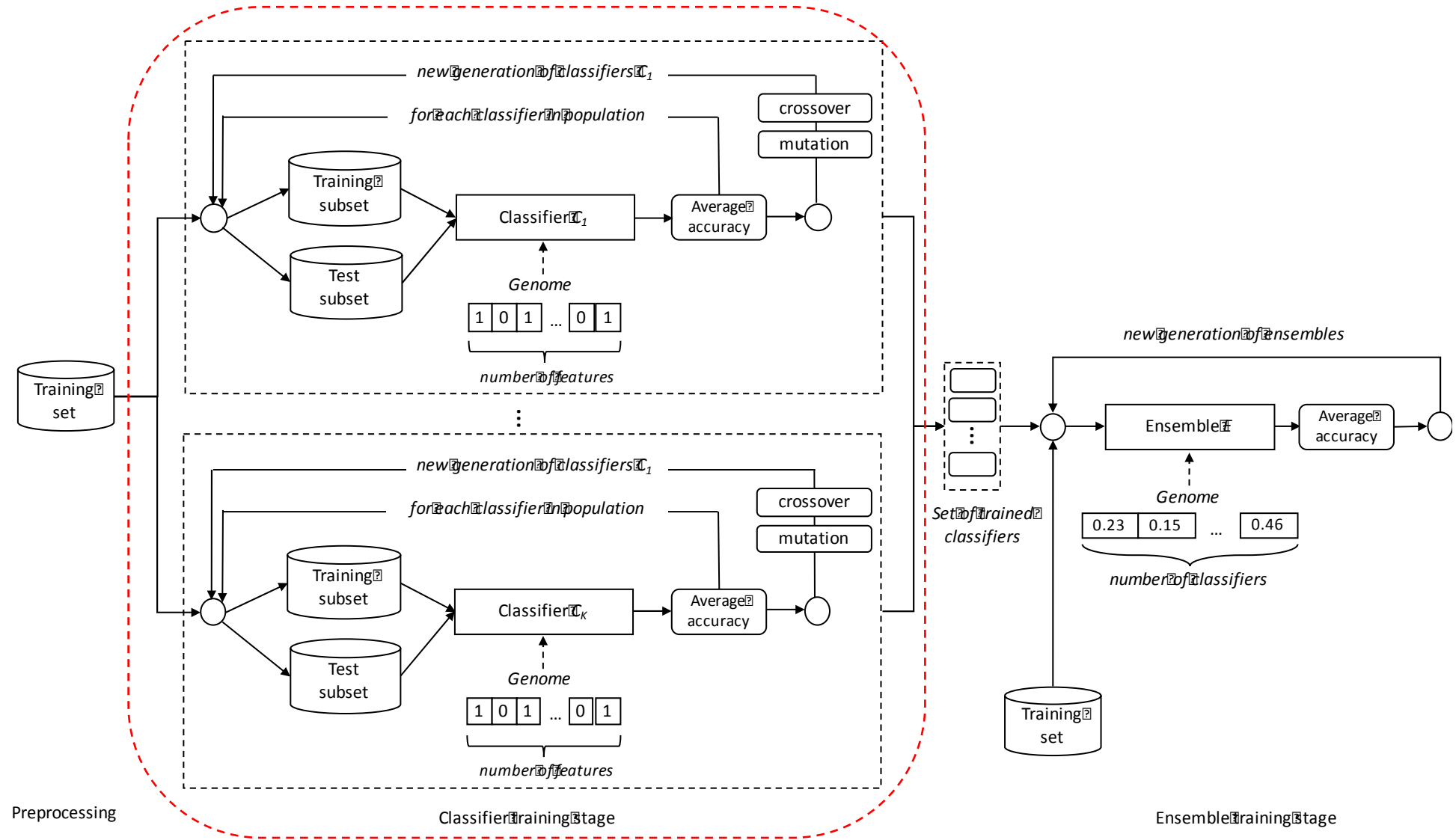


3: Multi-classifier system design



kNN – k Nearest Neighbors
DT – Decision Tree
LR – Logistic Regression
NB – Naive Bayes
SVM – Support Vector Machine

Feature Selection

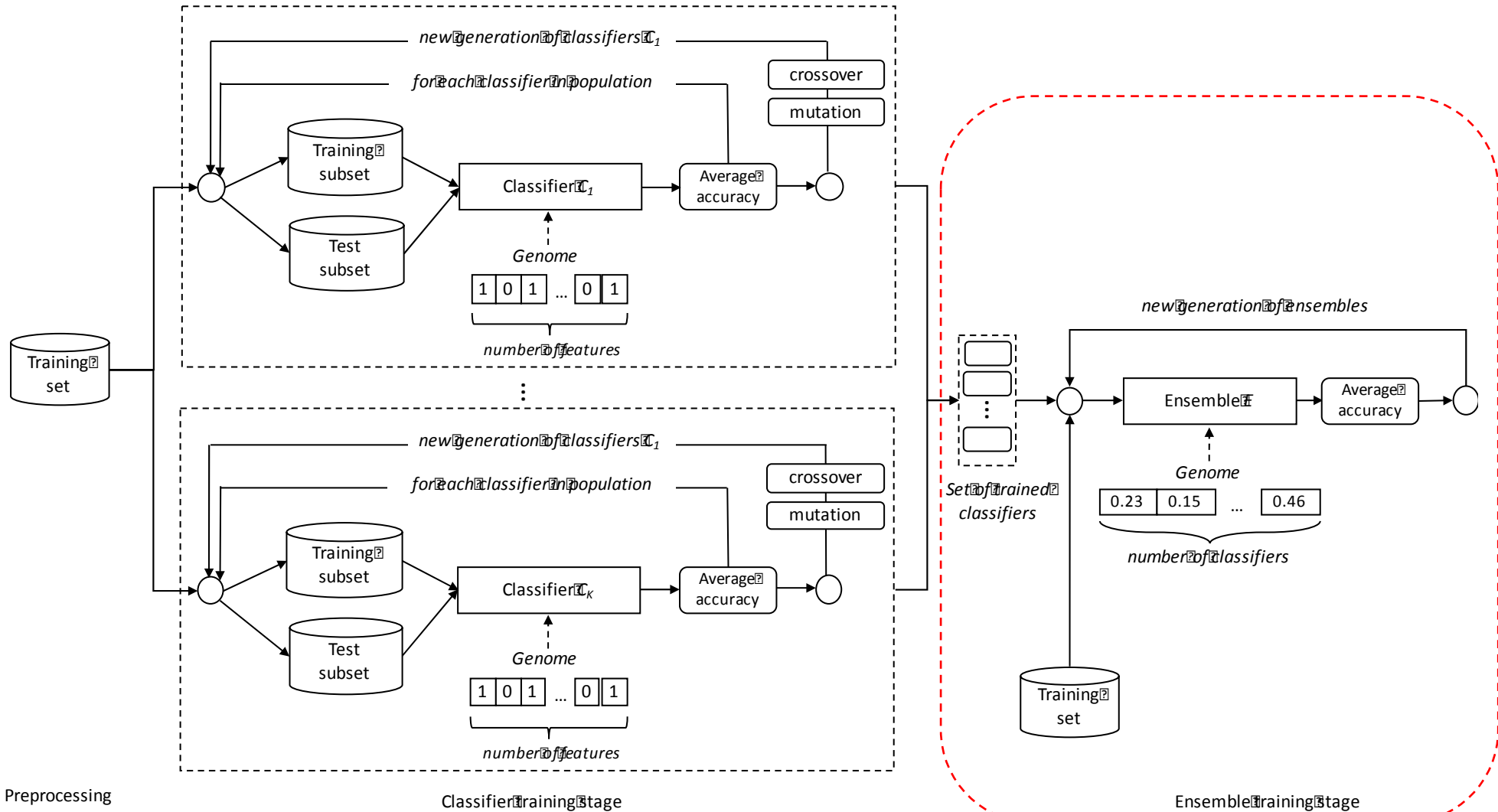


Results of base classifiers training

Classifier	Accuracy		Number of selected features	Precision / recall
	Before wrapping (N=41)	After wrapping		
KNN	0.526	0.558 ± 0.100	21	0.581 / 0.632
LR	0.536	0.585 ± 0.061	14	0.589 / 0.624
NB	0.542	0.577 ± 0.020	16	0.598 / 0.614
DT	0.530	0.530 ± 0.050	17	0.565 / 0.543
SVM	0.552	0.552 ± 0.059	18	0.595 / 0.612

$$accuracy = \frac{TP + TN}{TP + FP + TN + FN}; \quad precision = \frac{TP}{TP + FP}; \quad recall = \frac{TP}{TP + FN}$$

Voting Ensemble



Results of ensemble

Classifier	Accuracy		Number of selected features	Precision / recall
	Before wrapping (N=41)	After wrapping		
KNN	0.526	0.558 ± 0.100	21	0.581 / 0.632
LR	0.536	0.585 ± 0.061	14	0.589 / 0.624
NB	0.542	0.577 ± 0.020	16	0.598 / 0.614
DT	0.530	0.530 ± 0.050	17	0.565 / 0.543
SVM	0.552	0.552 ± 0.059	18	0.595 / 0.612
Ensemble		0.590		0.633 / 0.819

$$accuracy = \frac{TP + TN}{TP + FP + TN + FN}; \quad precision = \frac{TP}{TP + FP}; \quad recall = \frac{TP}{TP + FN}$$

Results

Daily prices of Alphabet Inc. shares (ticker GOOG)



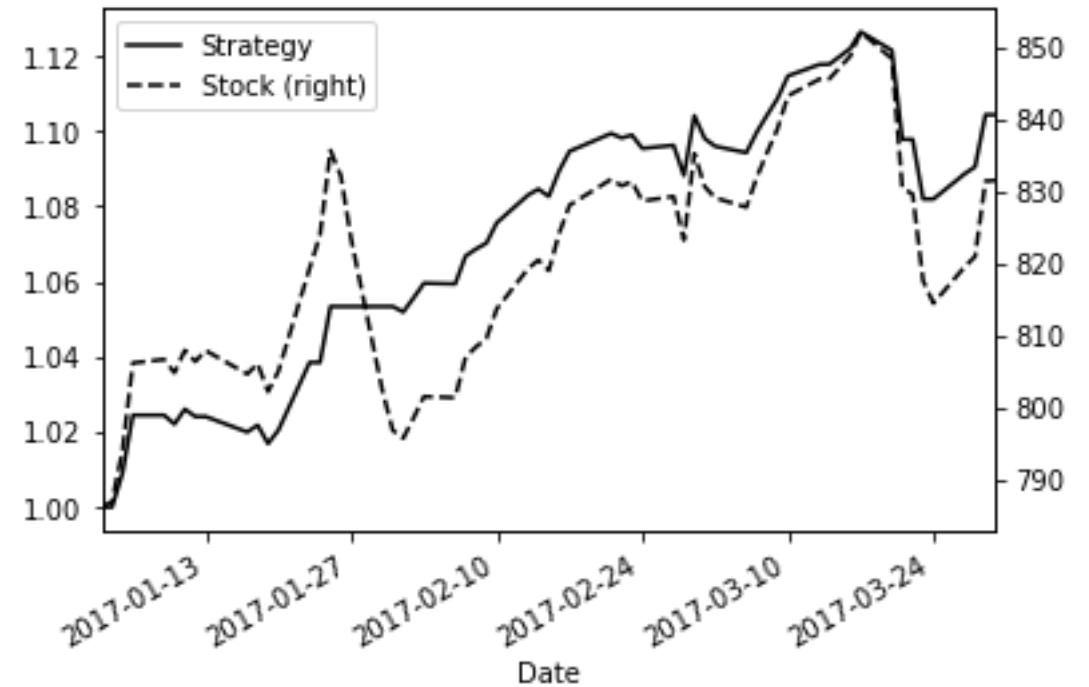
Return on train set (back testing)

Stock: 1.502

Algorithm: 1.78

Train set: two-year period 2015 – 2016

Test set: 1st Quarter 2017



Return on test set (back testing)

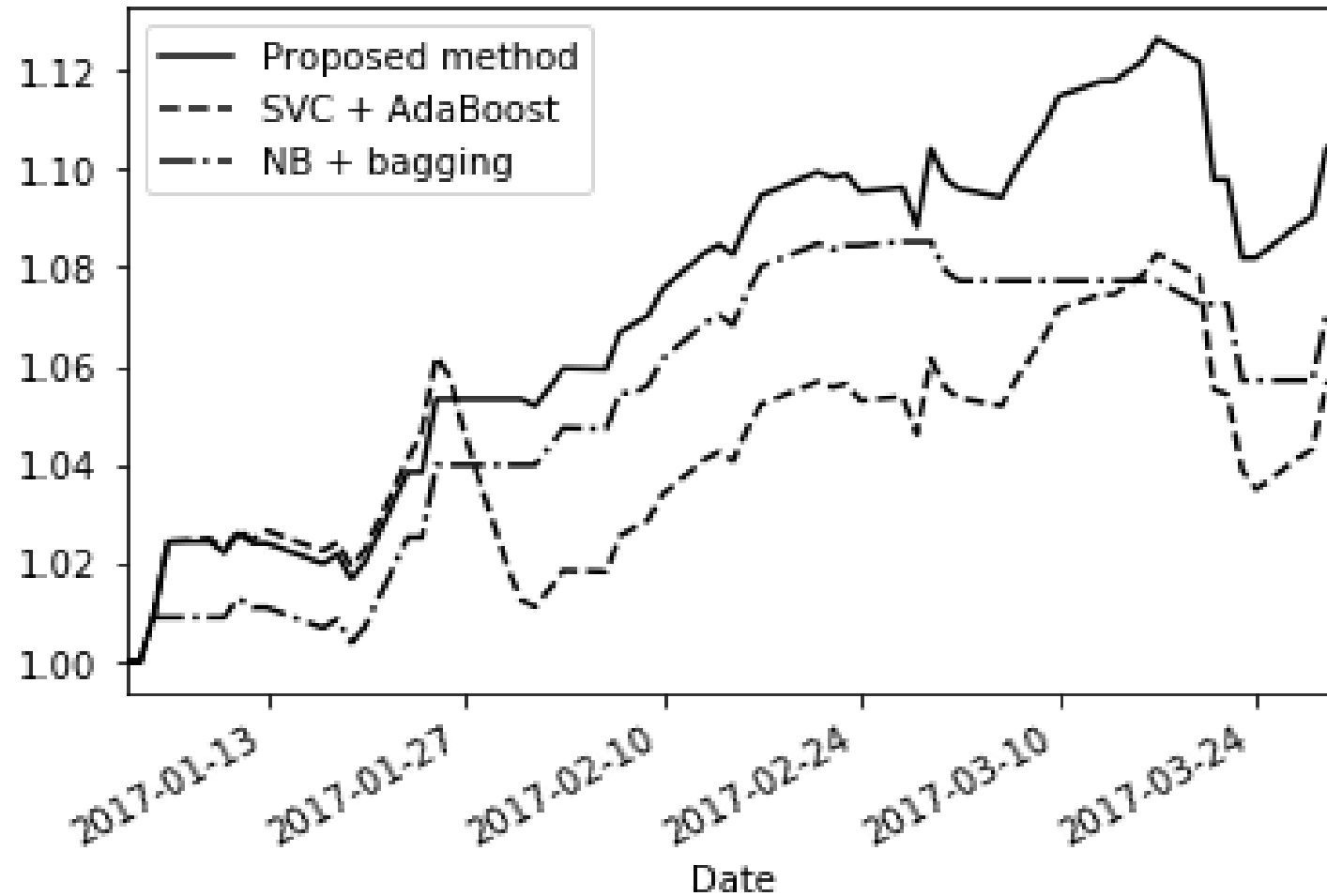
Stock: 1.08

Algorithm: 1.10

Comparison of different ensemble techniques

Method	Training set			Test set		
	accuracy	precision	recall	accuracy	precision	recall
BAGGING						
DT	0.988	0.985	0.992	0.508	0.643	0.474
kNN	0.687	0.676	0.744	0.377	0.500	0.316
NB	0.575	0.585	0.585	0.590	0.651	0.737
LR	0.563	0.565	0.643	0.574	0.667	0.632
SVC	0.575	0.585	0.589	0.492	0.667	0.368
ADABOOST						
DT	1.000	1.000	1.000	0.459	0.609	0.368
SVC	0.512	0.512	1.000	0.623	0.623	1.000
NB	0.569	0.575	0.609	0.541	0.625	0.658
OTHER TECHNIQUES						
Gradient Boosting	0.978	0.981	0.977	0.459	0.619	0.342
Random Forest	0.980	0.992	0.969	0.492	0.684	0.342
ExtraTrees	1.000	1.000	1.000	0.443	0.577	0.395
Proposed Method	0.744	0.698	0.880	0.590	0.633	0.816

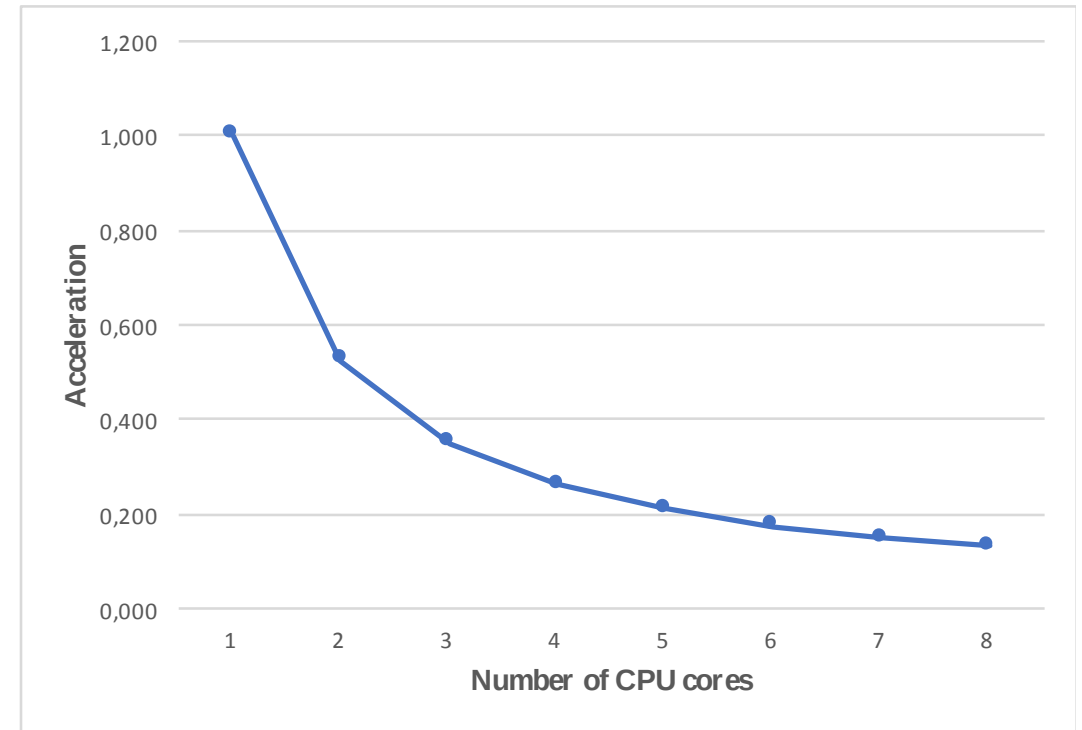
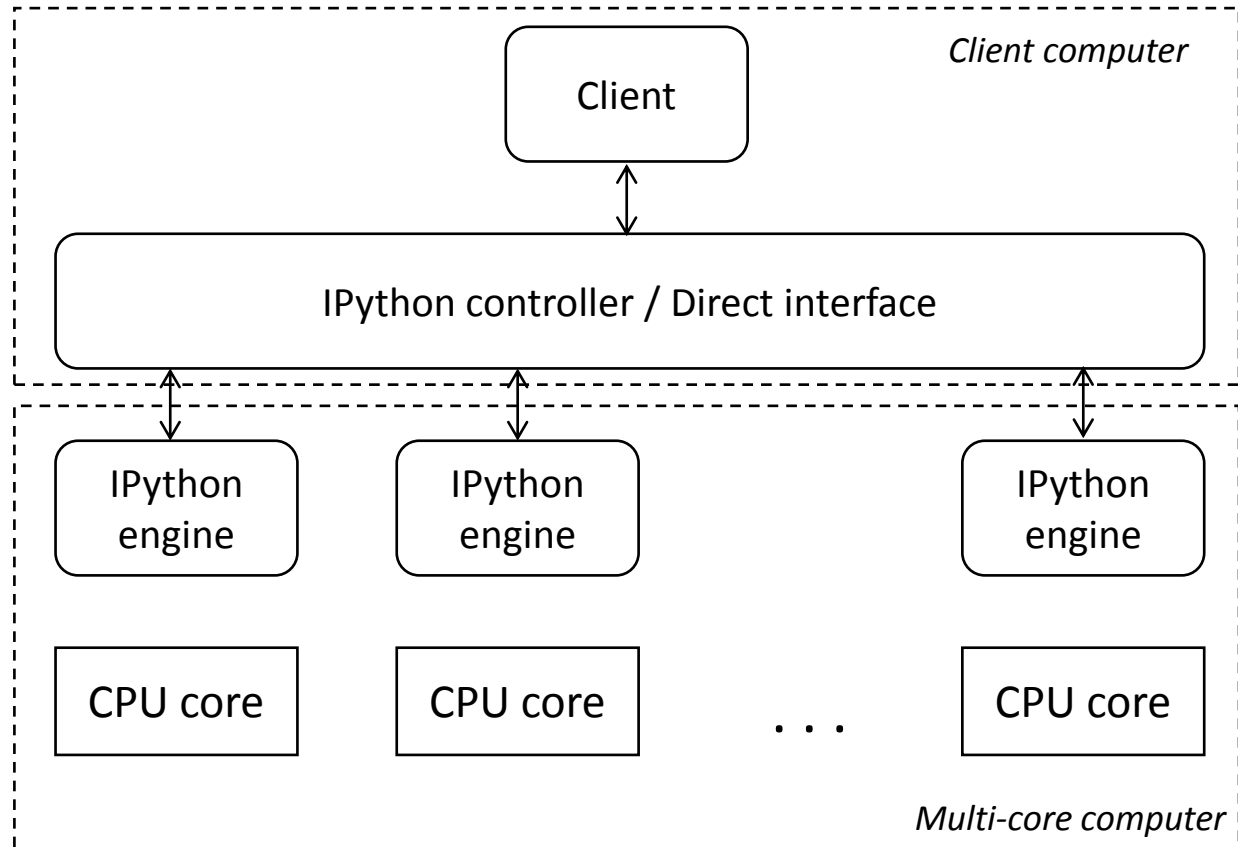
Comparison of three trading strategies



Various Assets

Company	Industry	Ensemble	accuracy	Back testing (train set)		Real testing (test set)	
		Test set	Train set	Price change	Return	Price change	Return
Alphabet	ITC	0.744	0.590	1.502	1.781	1.055	1.104
Amgen	Pharma	0.785	0.519	0.969	2.491	1.096	1.109
Apple	ITC	0.709	0.607	1.133	11.173	1.242	1.246
Exxon Mobile	Oil	0.714	0.541	0.932	8.300	0.799	1.168
General Electric	Manuf.	0.750	0.507	1.371	2.194	0.948	1.003
Gilead Sciences	Pharma	0.881	0.516	0.766	11.436	0.923	1.001
HSBC	Finance	0.889	0.508	0.997	7.296	1.024	1.042
JPMorgan Chase	Finance	0.775	0.514	1.497	10.453	1.013	1.040
Shell	Oil	0.765	0.581	0.981	2.913	0.972	1.013
United Techn.	Manuf.	0.877	0.505	1.019	1.970	1.018	1.027

Parallel Implementation



Thank you for your attention