

Gradient Boosting

Boosting algorithm

1. Initialize $f(x) = 0, r = y$

2. For $b = 1, 2, \dots, B$, repeat

a) Fit a tree $f_b(x)$ to the training data (X, \underline{r})

b) $f(x) \leftarrow f(x) + \underline{\lambda} f_b(x)$

c) $r \leftarrow r - \lambda f_b(x)$

3. output $\sum_{b=1}^B \lambda f_b(x)$



Gradient Boosting

1. Initialize $f(x) = 0, r = \underline{-g}$

$$\boxed{\frac{y - f(x)}{L(x, y, g_p^{f(x)})}} = \frac{1}{2} (y - f(x))^2$$

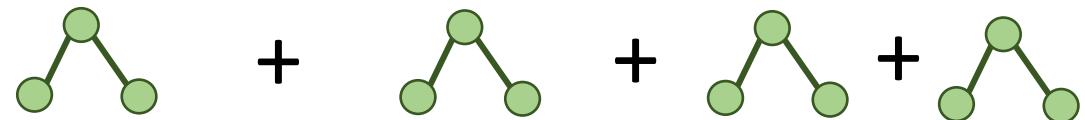
2. For $b = 1, 2, \dots, B$, repeat

a) Fit a tree $\underline{f_b(x)}$ to the training data (X, r)

b) $f(x) \leftarrow f(x) + \lambda f_b(x)$

c) $r \leftarrow r - \lambda f_b(x)$

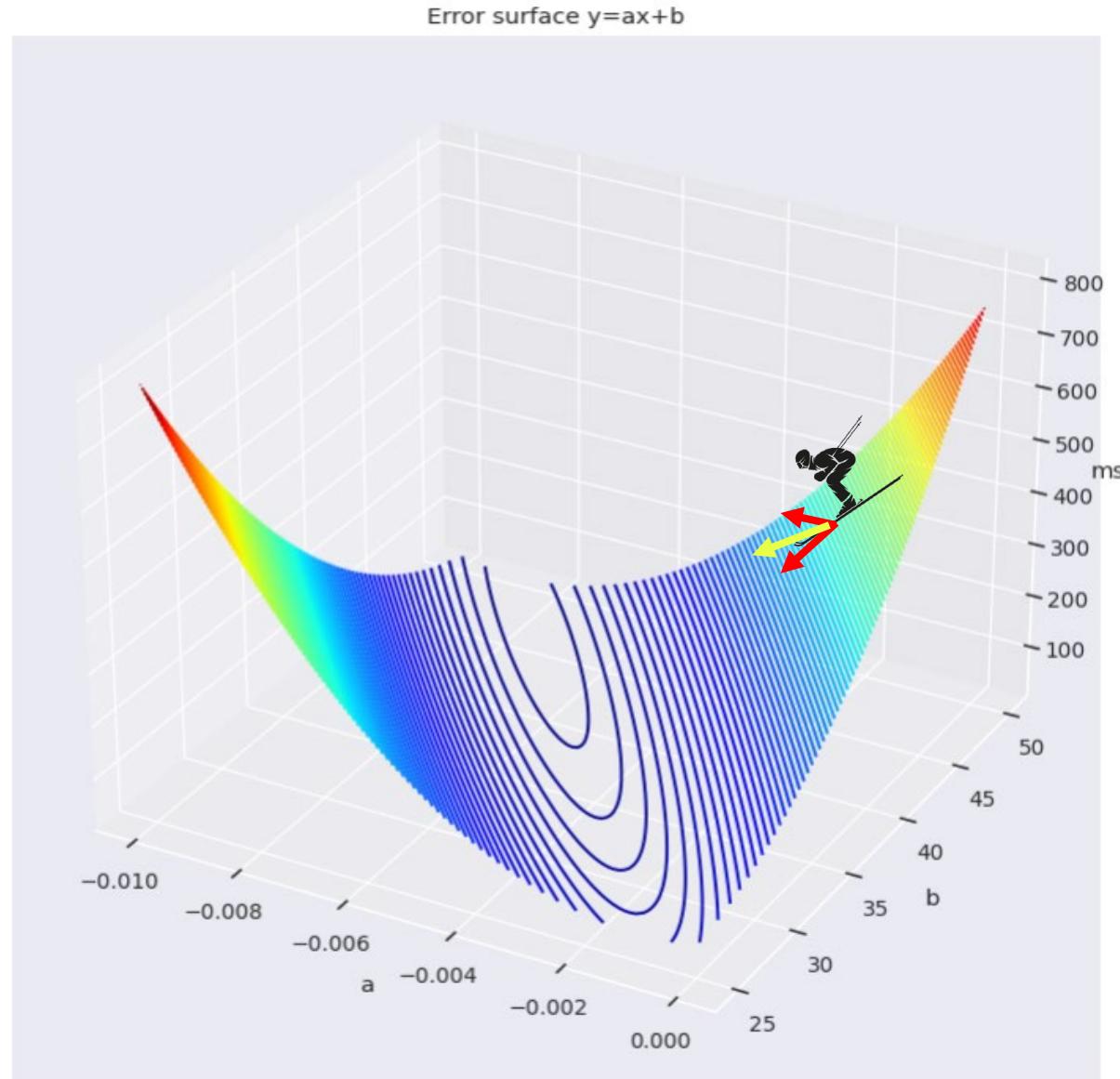
3. output $\sum_{b=1}^B \lambda f_b(x)$



Gradient Boosting

1. Initialize $\underline{f_0(x_i)} = \operatorname{argmin}_{\theta_0} \sum_{i=1}^N L(x_i, y_i; \theta_0)$
2. For $b = 1, 2, \dots, B$, repeat
 - a) Calculate the negative gradient $r_{ib} = -\frac{\partial L(y_i, f(x_i))}{\partial f(x_i)} \Big|_{f=f_{b-1}}$
 - b) Fit a tree $f_b(x_i)$ to the training data $(x_i, r_{ib}) \rightarrow \underline{\theta_b}$
 - c) Update loss $L(x, y; f_b)$
 - d) Update function $f(x) \leftarrow f(x) + \lambda f_b(x)$
3. output $\sum_{b=1}^B \lambda f_b(x)$

Why Gradient?



Performance Comparison

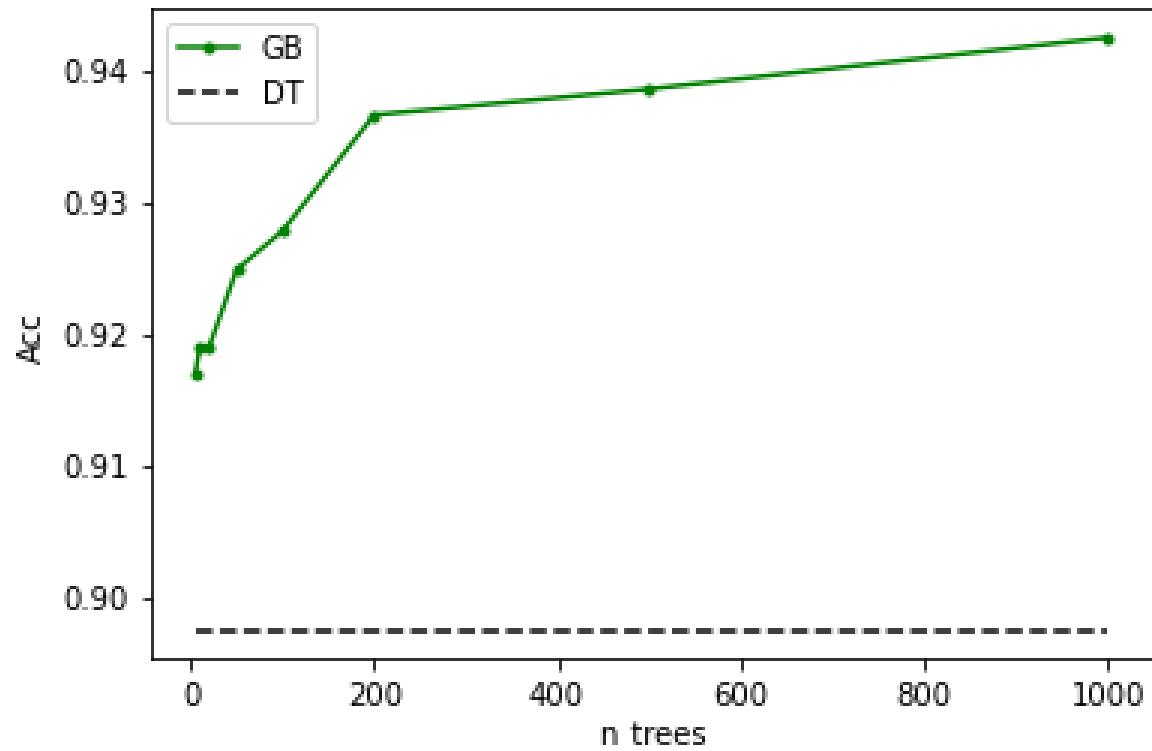
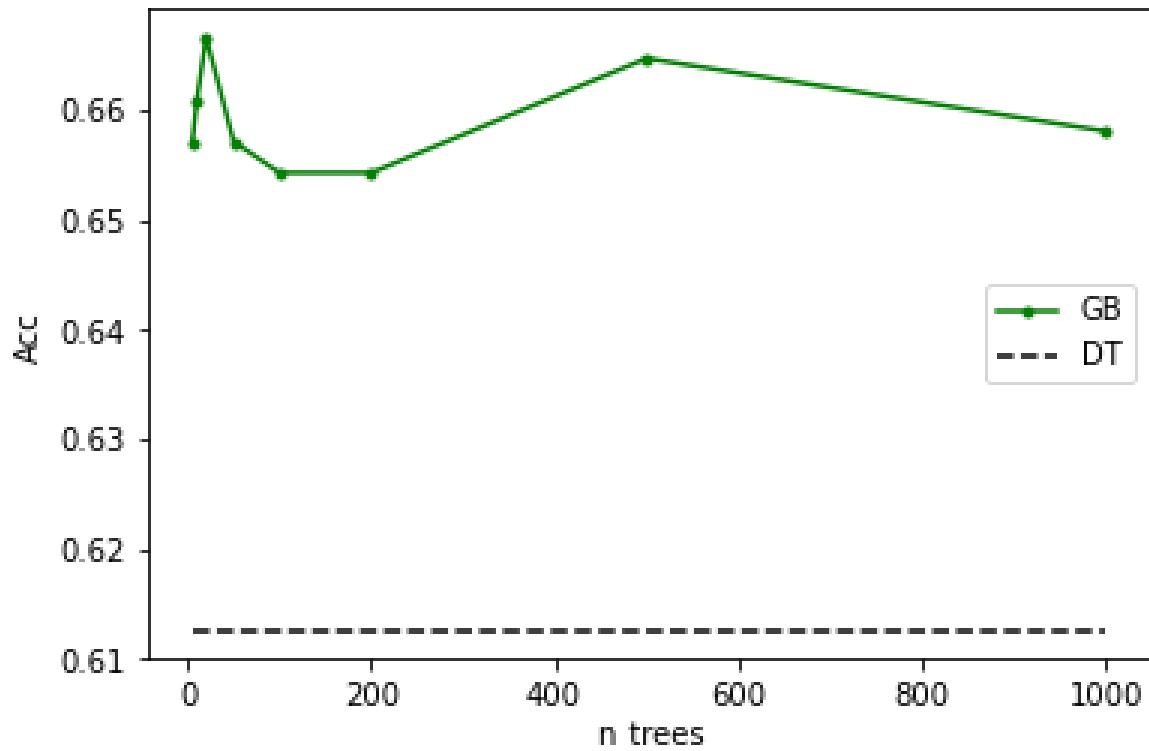
Data 1.

- 13 features,
- 5200+ samples
- DT performance 0.61

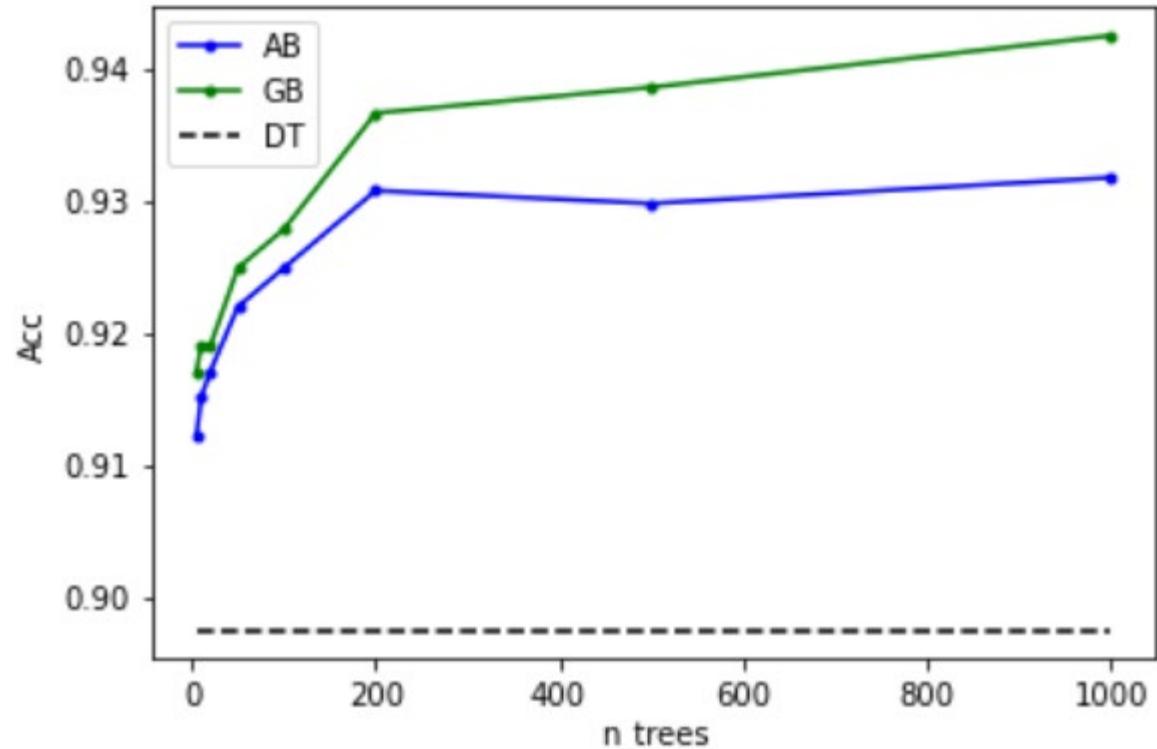
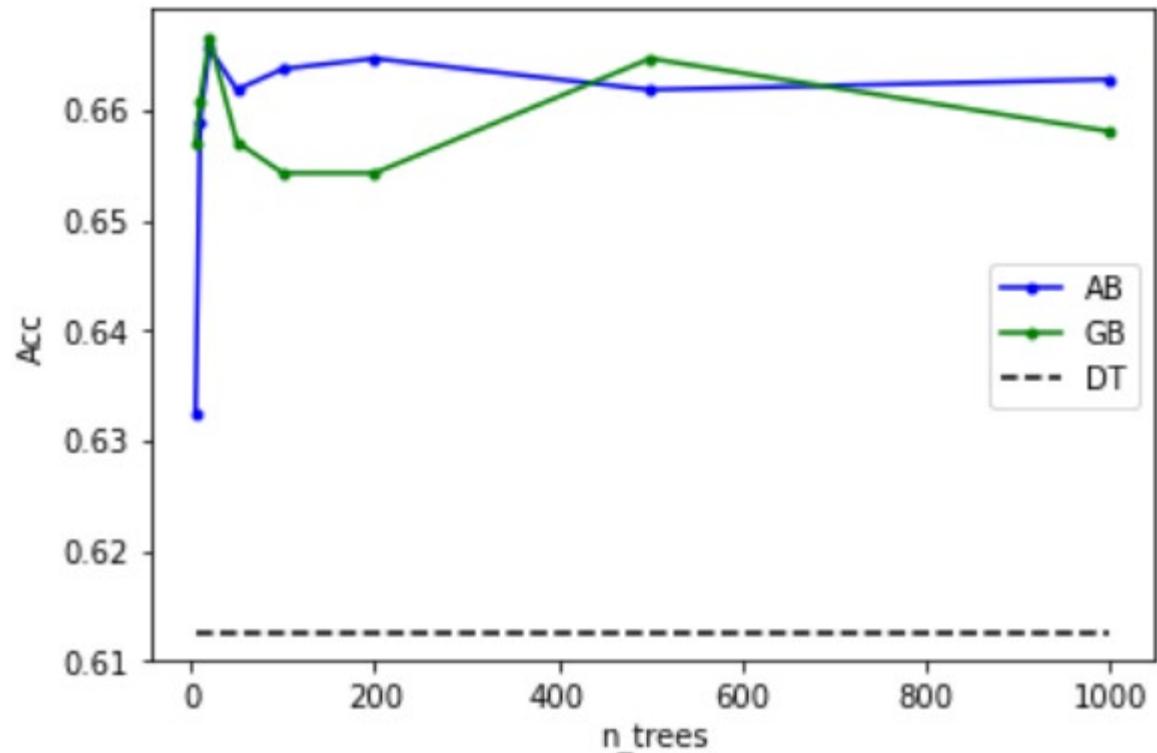
Data 2.

- 20 features,
- 5100+ samples
- DT performance 0.89

Performance Comparison

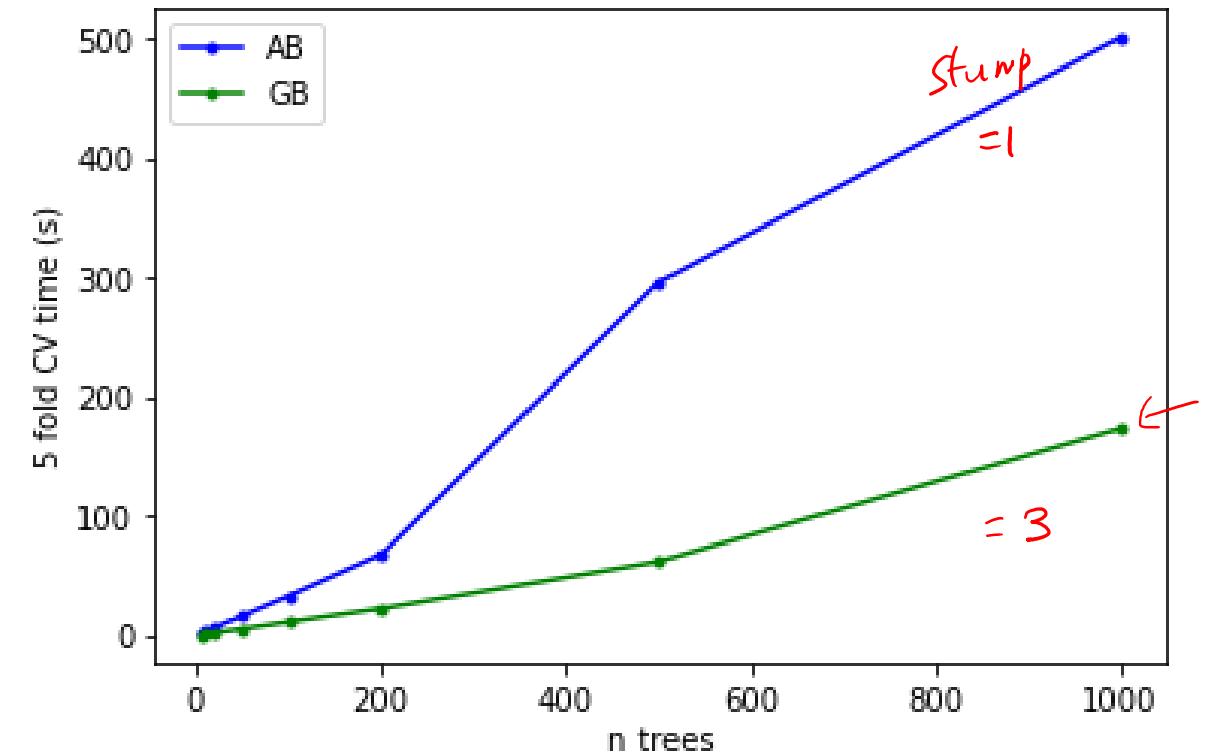
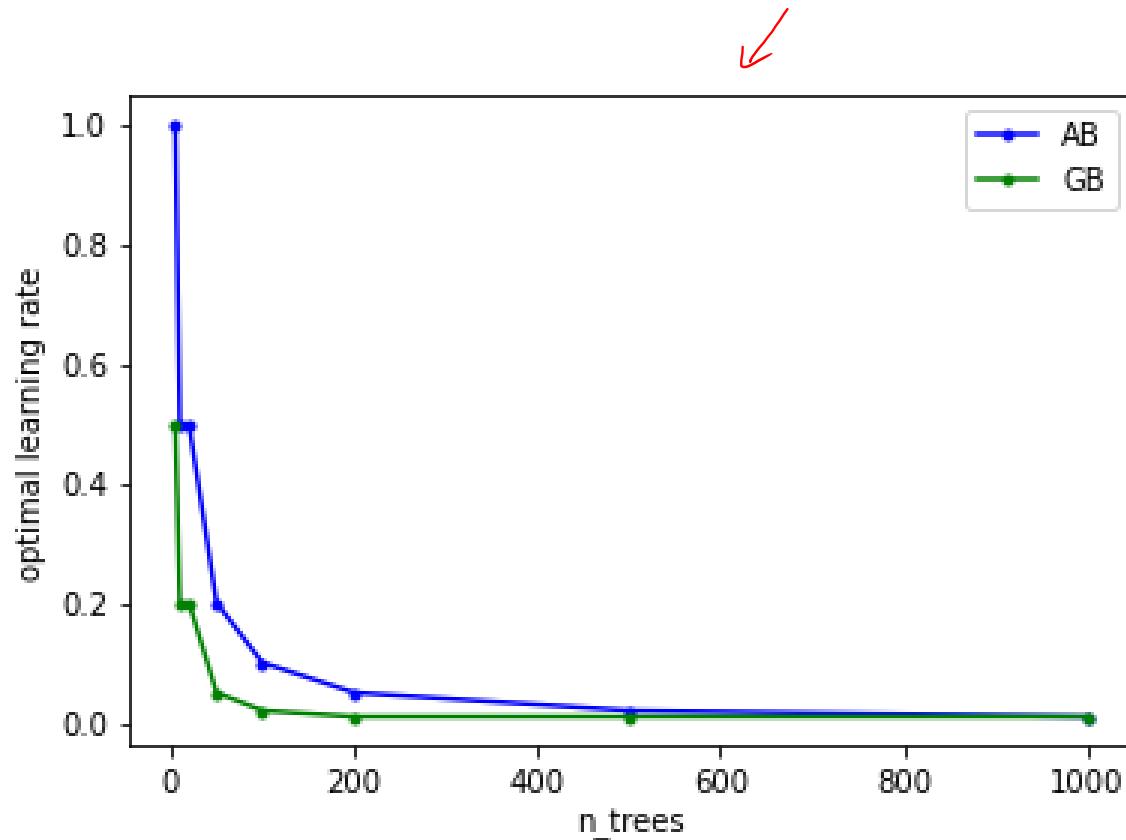


Performance Comparison /w AdaBoost

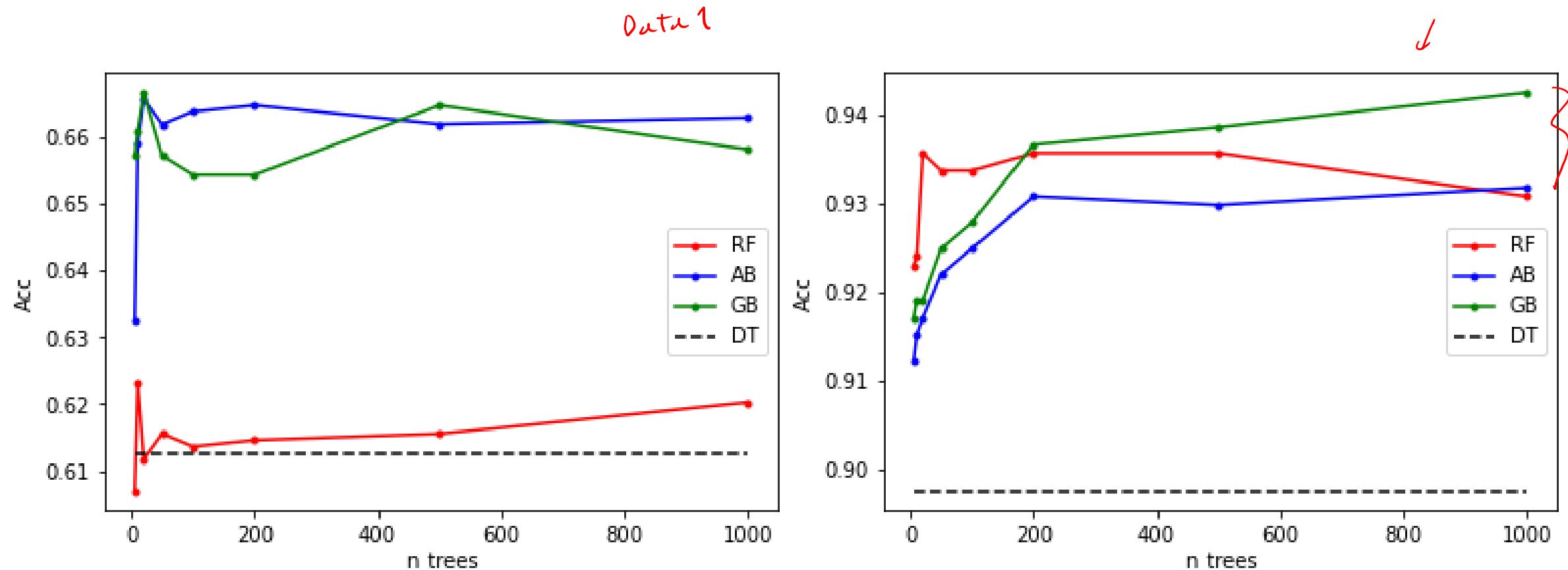


Performance Comparison /w AdaBoost

Data 1.



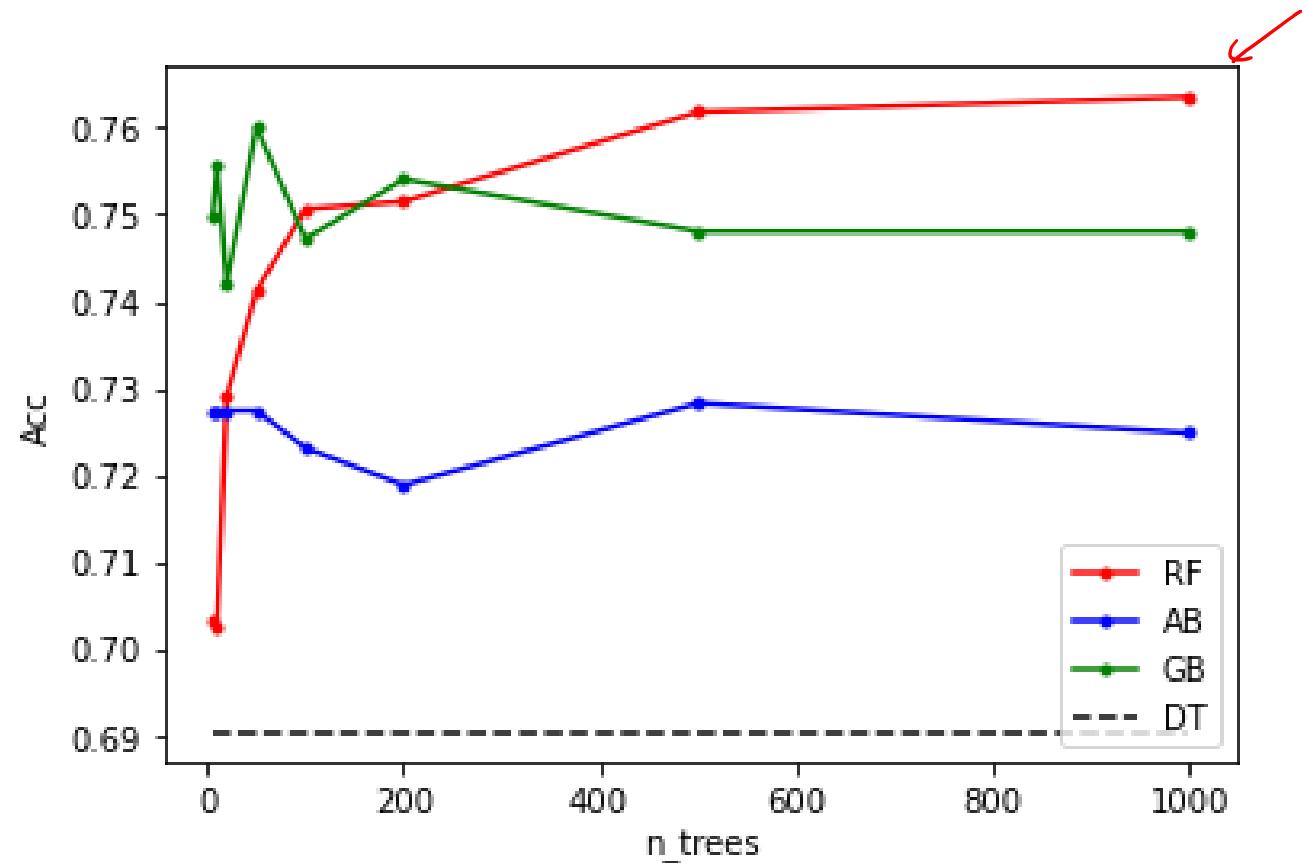
Performance Comparison /w Random Forest



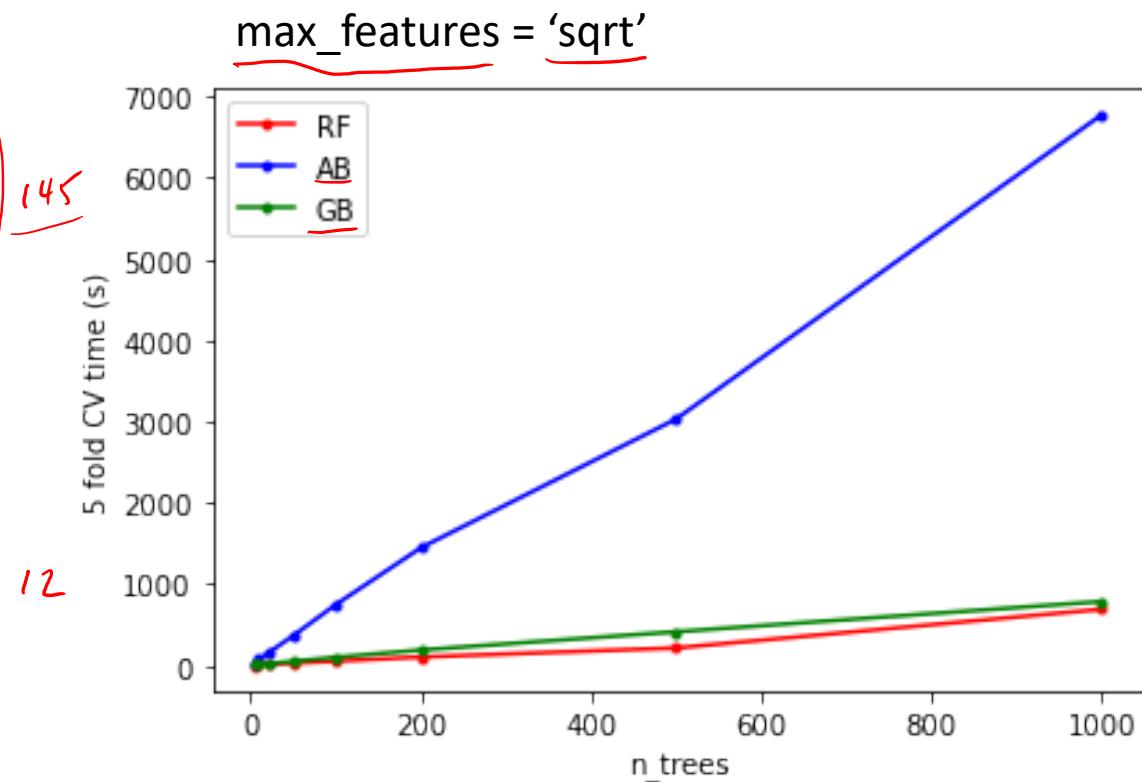
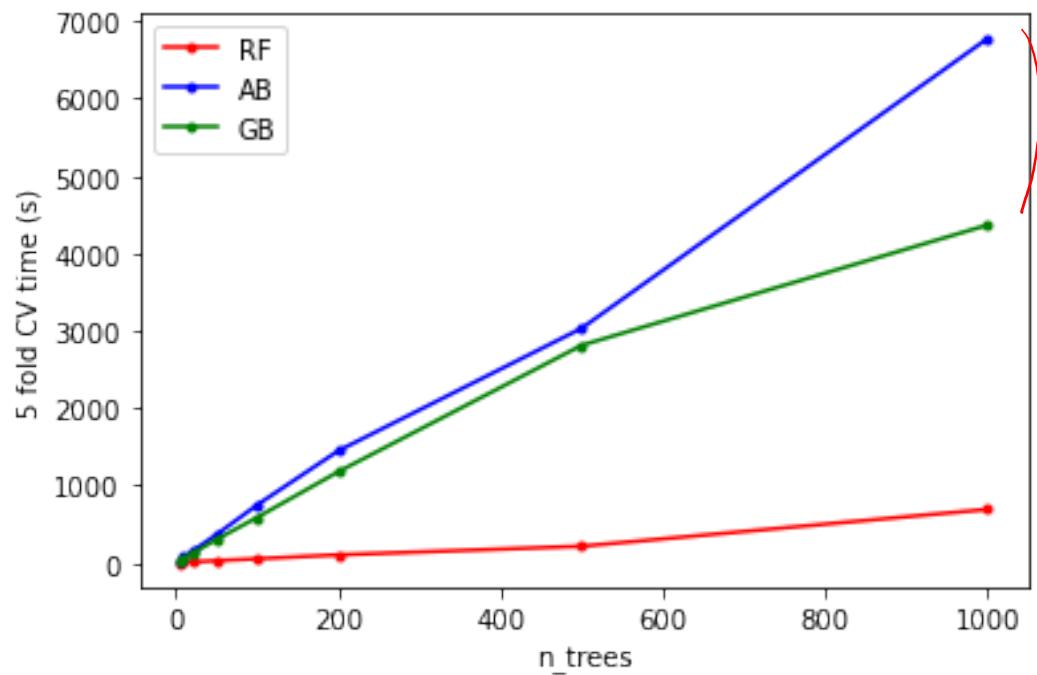
Performance Comparison /w Random Forest

Data 3.

- 145 features,
- ~3000 samples
- DT performance 0.69



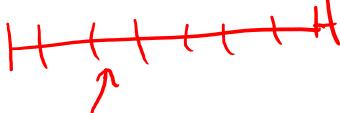
Performance Comparison /w Random Forest



Other useful packages

- XGBoost →
- lightGBM (Histogram-based)
- ExtraTree

~~Histogram-based~~

No bugs , 

Other useful packages

User guide: See the [Ensemble methods](#) section for further details.

| | |
|--|---|
| <code>ensemble.AdaBoostClassifier([...])</code> | An AdaBoost classifier. |
| <code>ensemble.AdaBoostRegressor([base_estimator, ...])</code> | An AdaBoost regressor. |
| <code>ensemble.BaggingClassifier([base_estimator, ...])</code> | A Bagging classifier. |
| <code>ensemble.BaggingRegressor([base_estimator, ...])</code> | A Bagging regressor. |
| <code>ensemble.ExtraTreesClassifier([...])</code> | An extra-trees classifier. |
| <code>ensemble.ExtraTreesRegressor([n_estimators, ...])</code> | An extra-trees regressor. |
| <code>ensemble.GradientBoostingClassifier(*[, ...])</code> | Gradient Boosting for classification. |
| <code>ensemble.GradientBoostingRegressor(*[, ...])</code> | Gradient Boosting for regression. |
| <code>ensemble.IsolationForest(*[, n_estimators, ...])</code> | Isolation Forest Algorithm. |
| <code>ensemble.RandomForestClassifier([...])</code> | A random forest classifier. |
| <code>ensemble.RandomForestRegressor([...])</code> | A random forest regressor. |
| <code>ensemble.RandomTreesEmbedding([...])</code> | An ensemble of totally random trees. |
| <code>ensemble.StackingClassifier(estimators[, ...])</code> | Stack of estimators with a final classifier. |
| <code>ensemble.StackingRegressor(estimators[, ...])</code> | Stack of estimators with a final regressor. |
| <code>ensemble.VotingClassifier(estimators, *[, ...])</code> | Soft Voting/Majority Rule classifier for unfitted estimators. |
| <code>ensemble.VotingRegressor(estimators, *[, ...])</code> | Prediction voting regressor for unfitted estimators. |
| <code>ensemble.HistGradientBoostingRegressor([...])</code> | Histogram-based Gradient Boosting Regression Tree. |
| <code>ensemble.HistGradientBoostingClassifier([...])</code> | Histogram-based Gradient Boosting Classification Tree. |



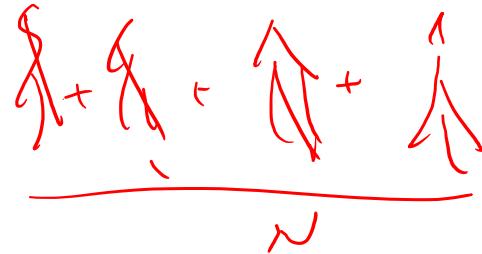
Recap

RF (Parallel)

vs.

Boosting (serial)

$$x + \lambda + \lambda + \lambda = f(x)$$



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