



Gradient Boosting

Boosting algorithm

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

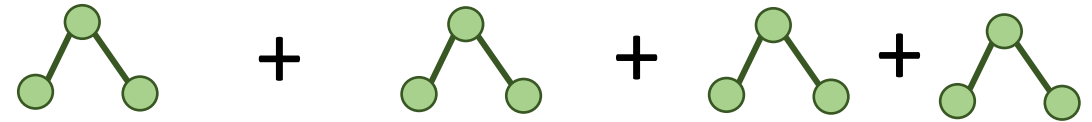
2. For $b = 1, 2, \dots, B$, repeat

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



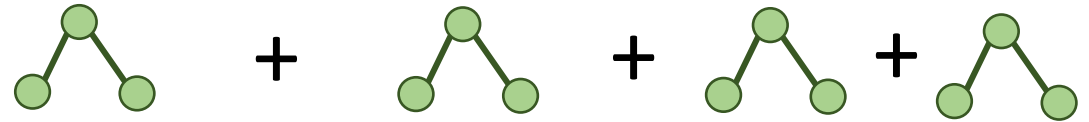
Gradient Boosting

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

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

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

a) Fit a tree $f_b(x)$ 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 $\underline{f_0(x_i)} = \underset{\theta_0}{\operatorname{argmin}} \sum_{i=1}^N L(x_i, y_i; \theta_0)$

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

a) Calculate the negative gradient $r_{ib} = - \frac{\partial L(y_i, f(x_i))}{\partial f(x_i)} \Big|_{f=f_{b-1}}$

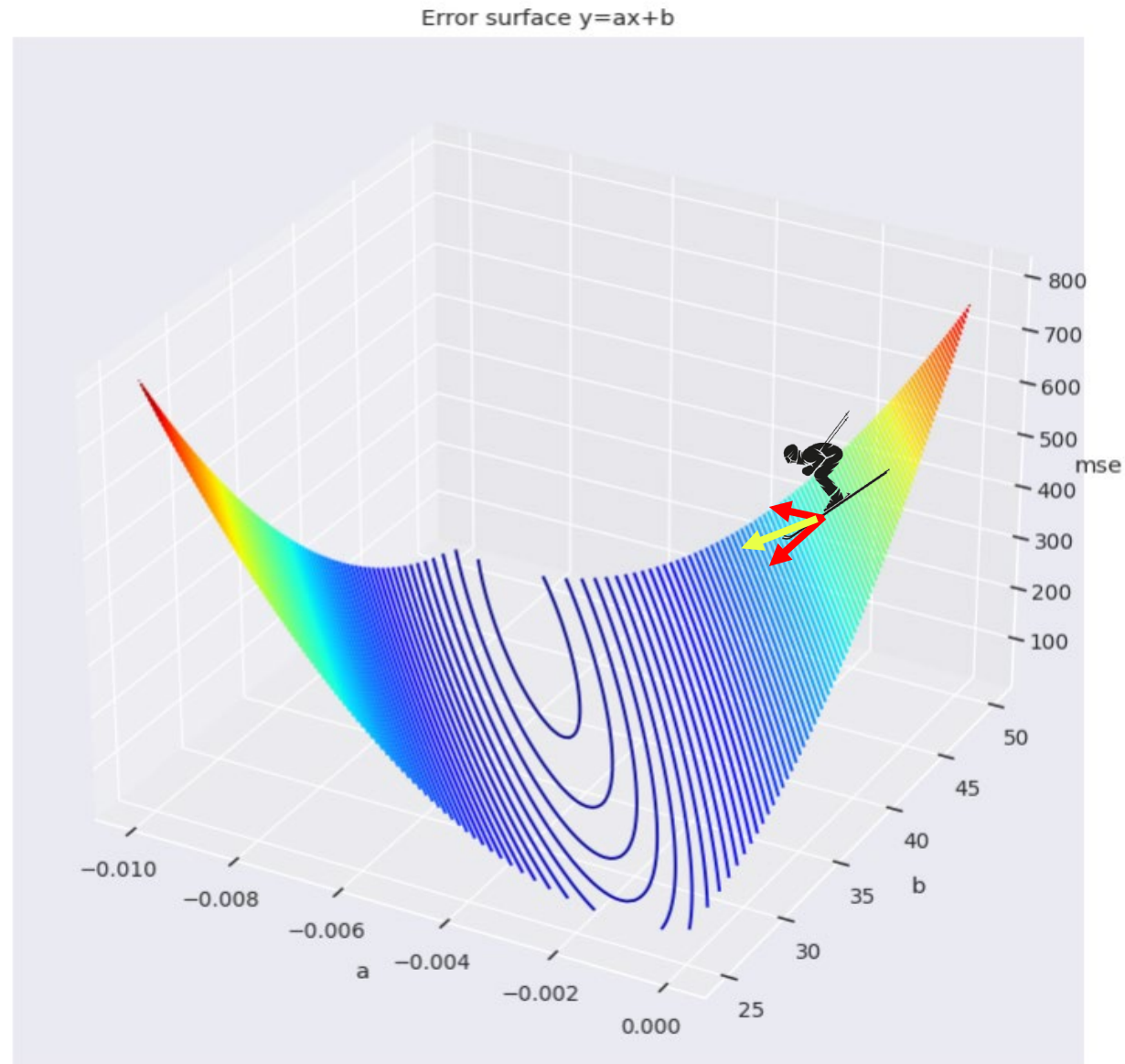
b) Fit a tree $f_b(x_i)$ to the training data $(x_i, r_{ib}) \rightarrow \underline{\theta_b}$

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?



Steepest descent

Performance Comparison

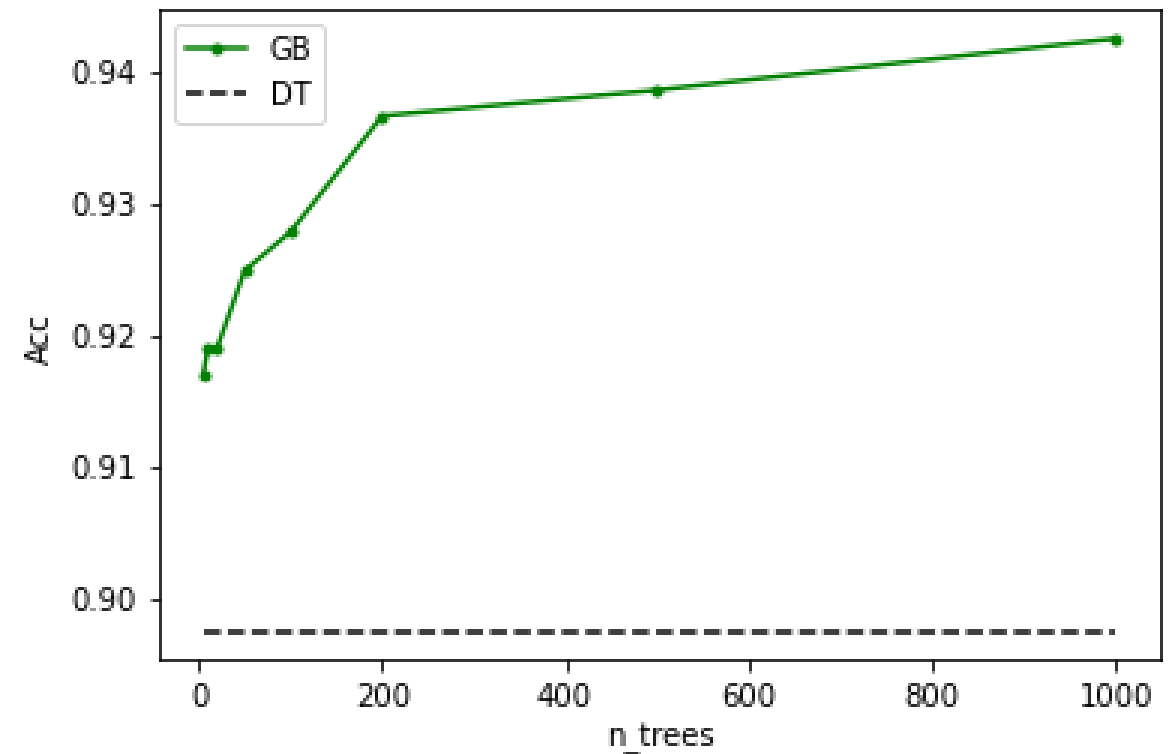
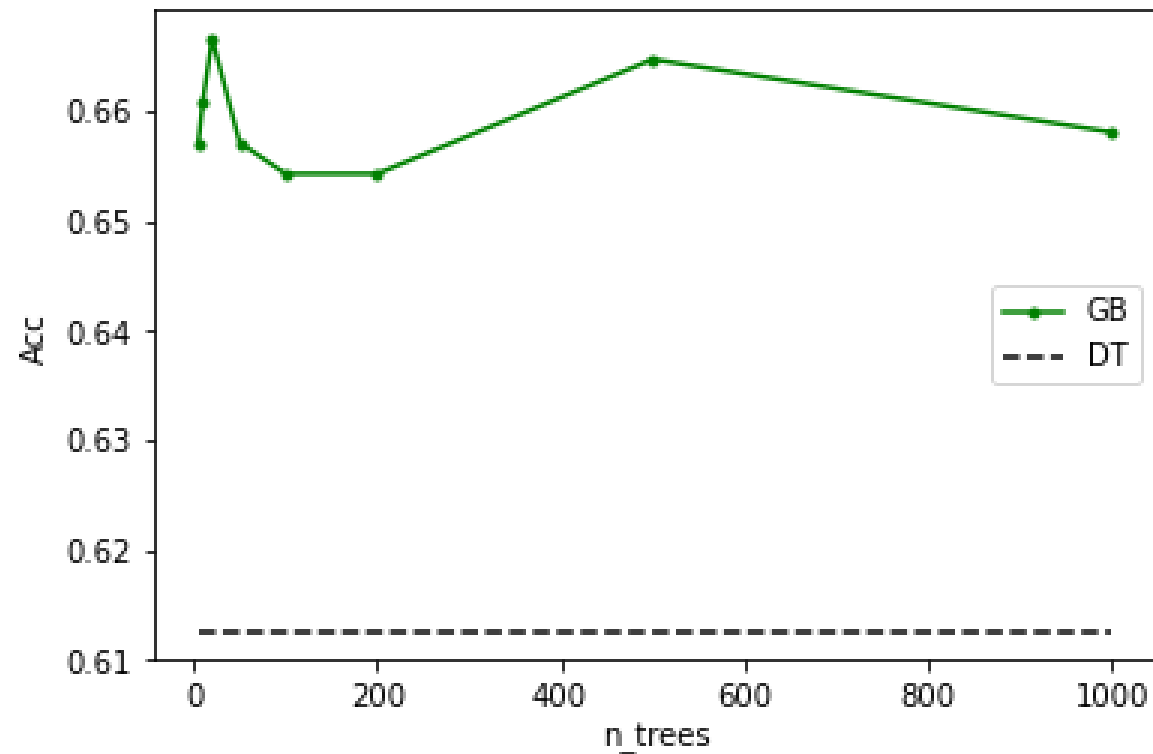
Data 1.

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

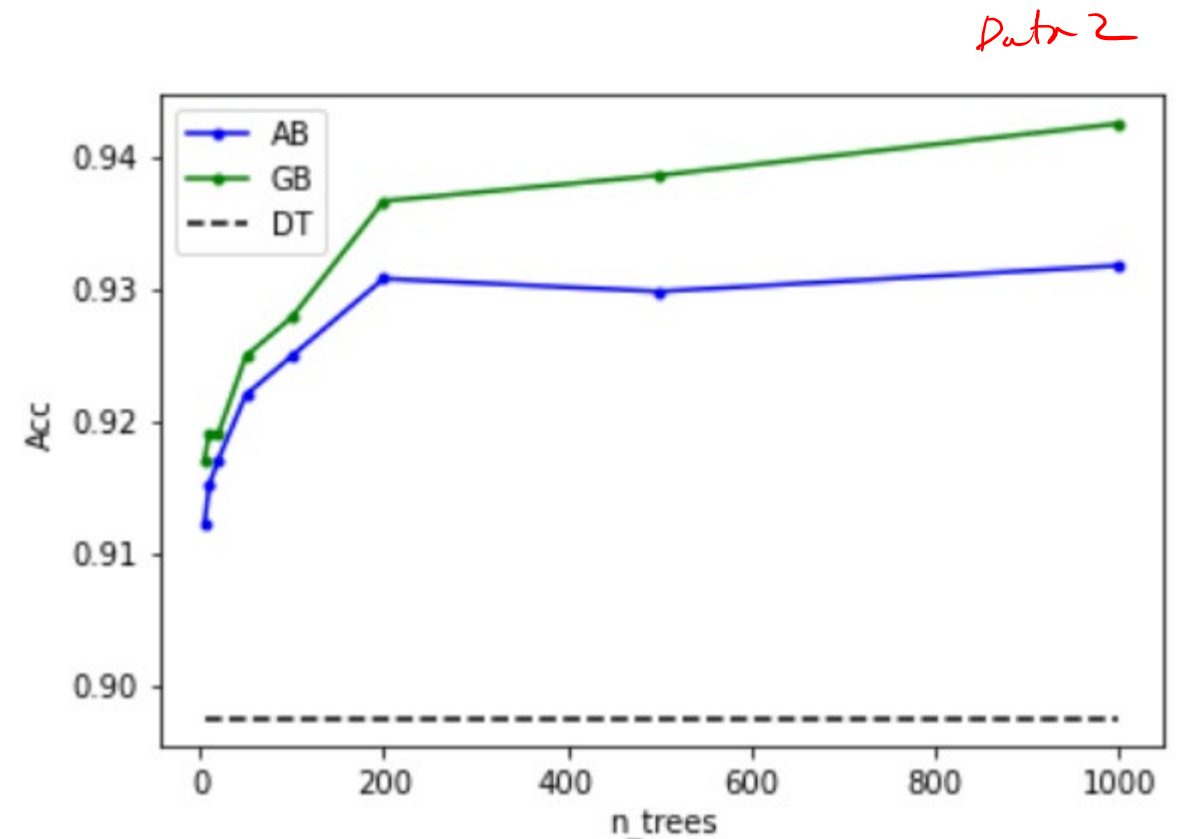
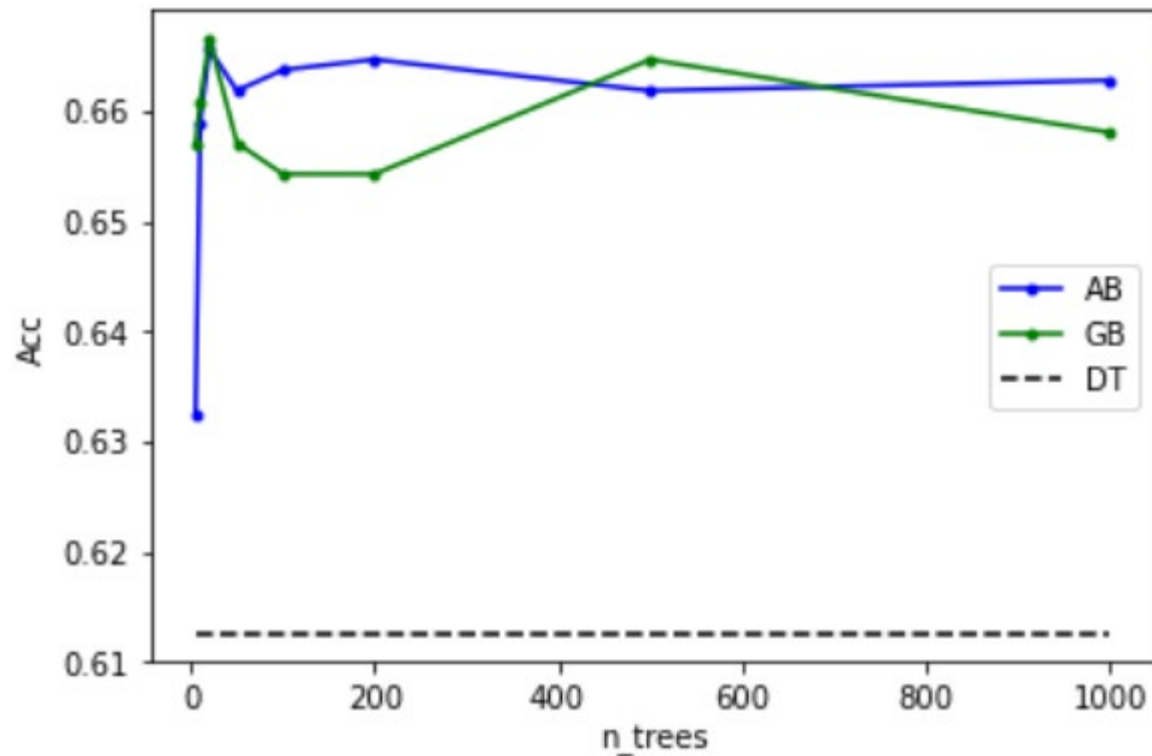
Data 2.

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

Performance Comparison

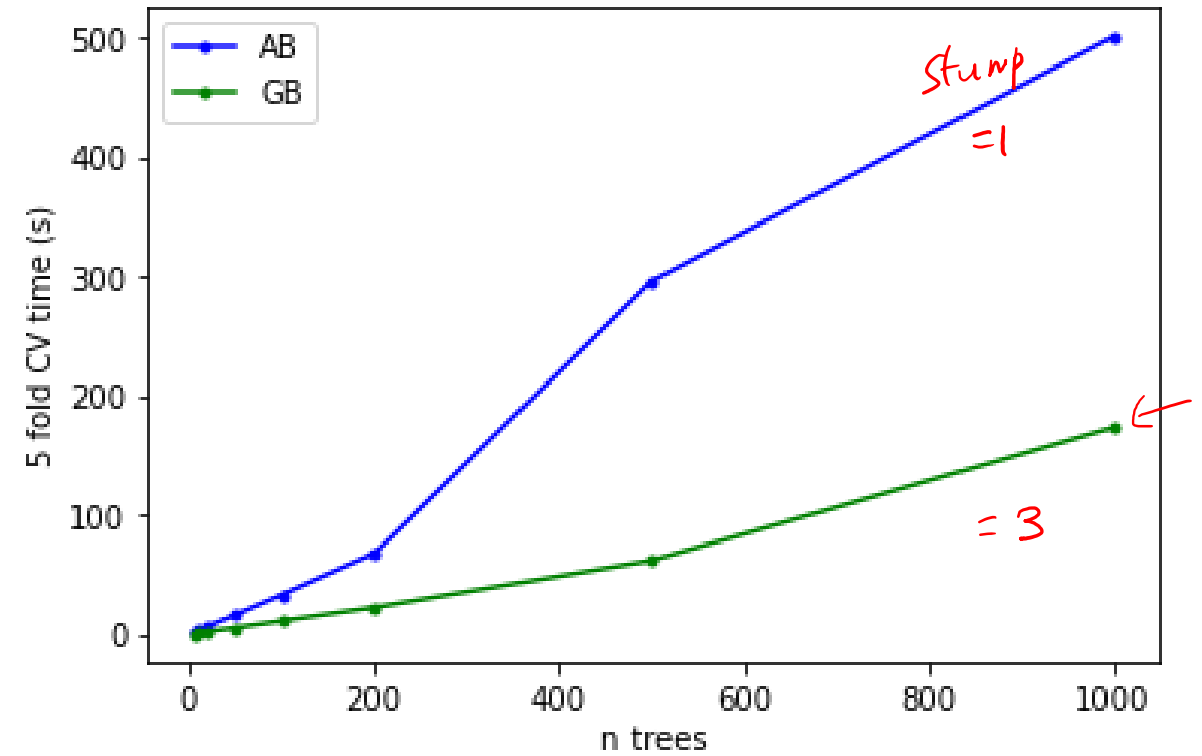
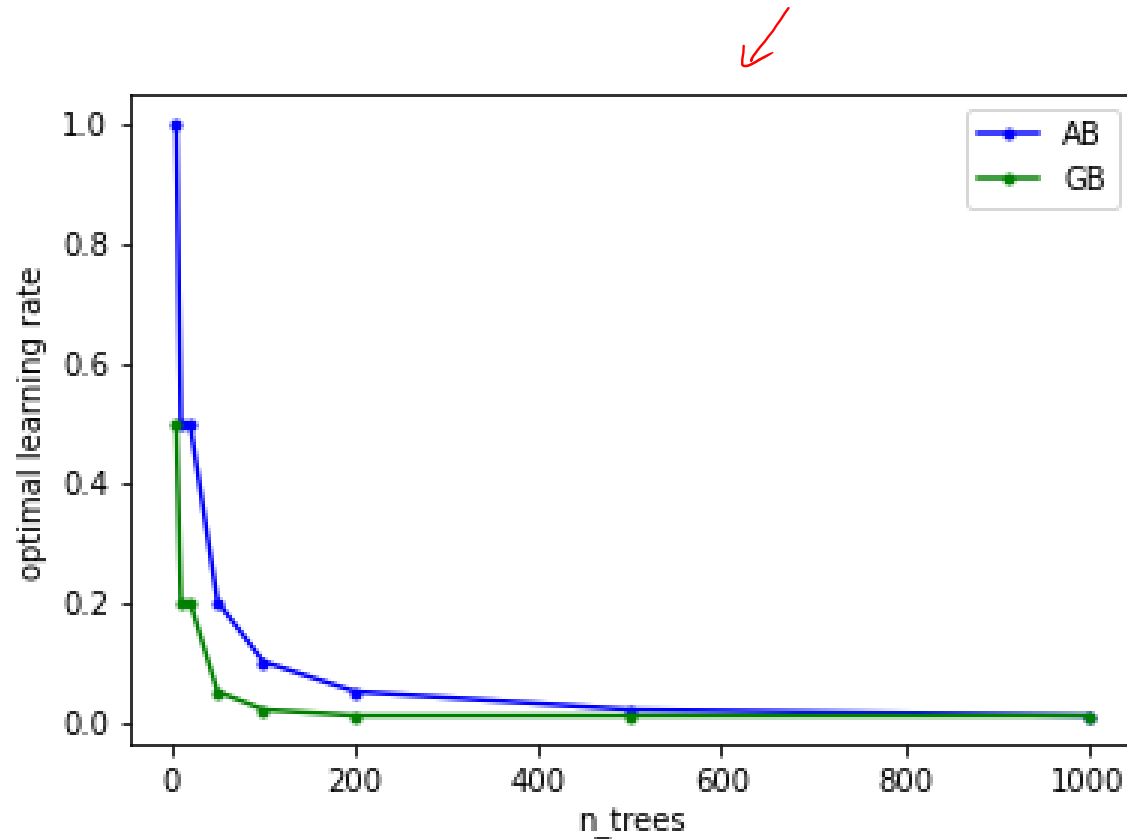


Performance Comparison /w AdaBoost



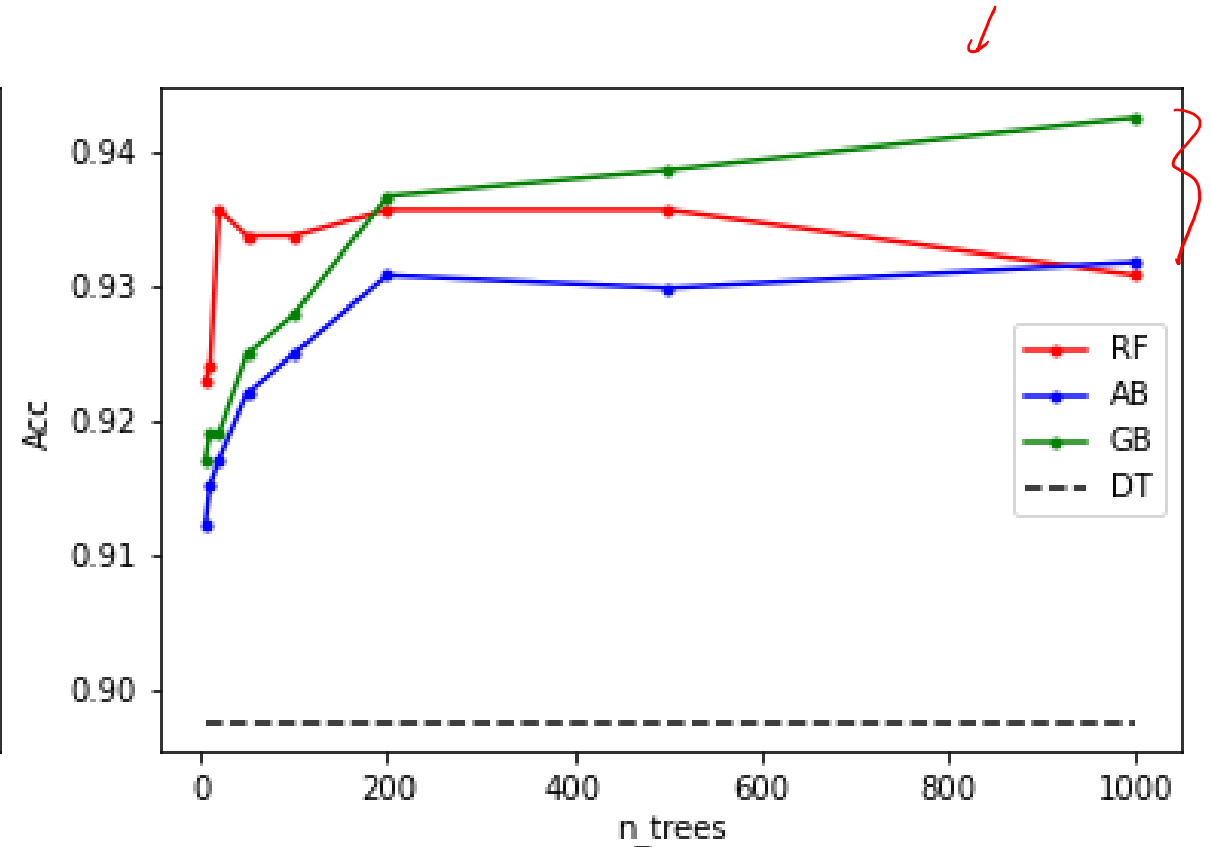
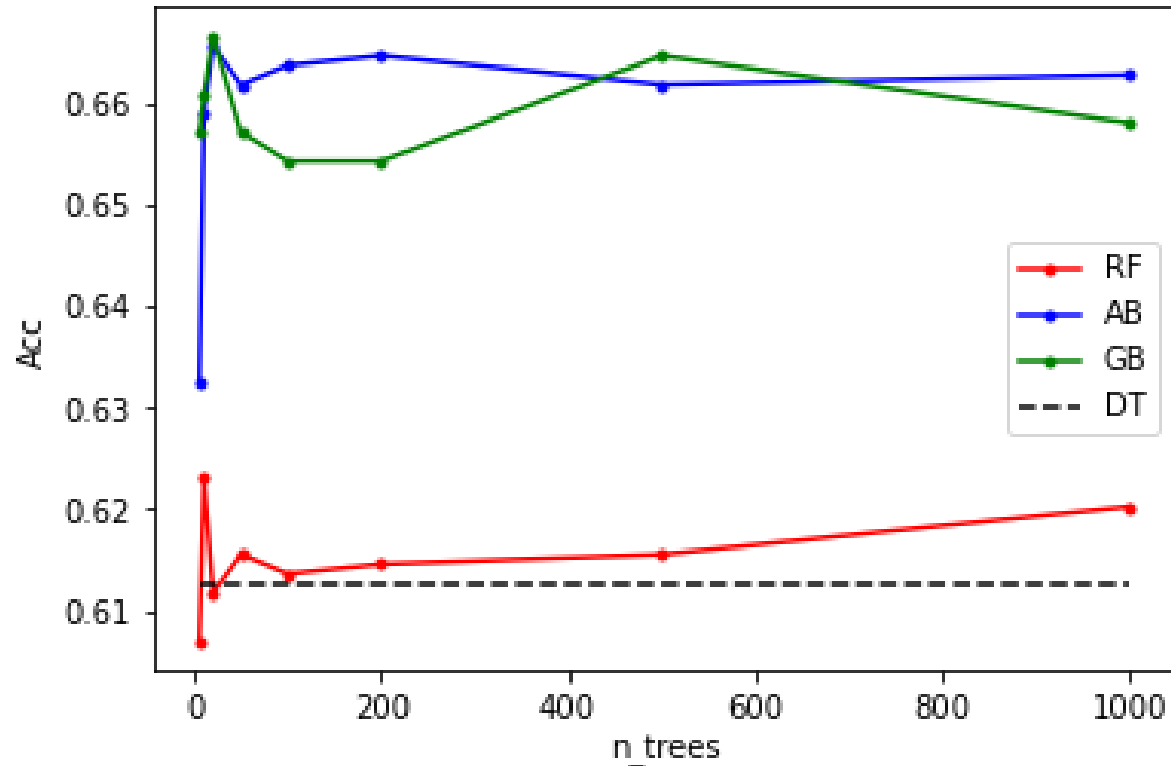
Performance Comparison /w AdaBoost

Data 1.



Performance Comparison /w Random Forest

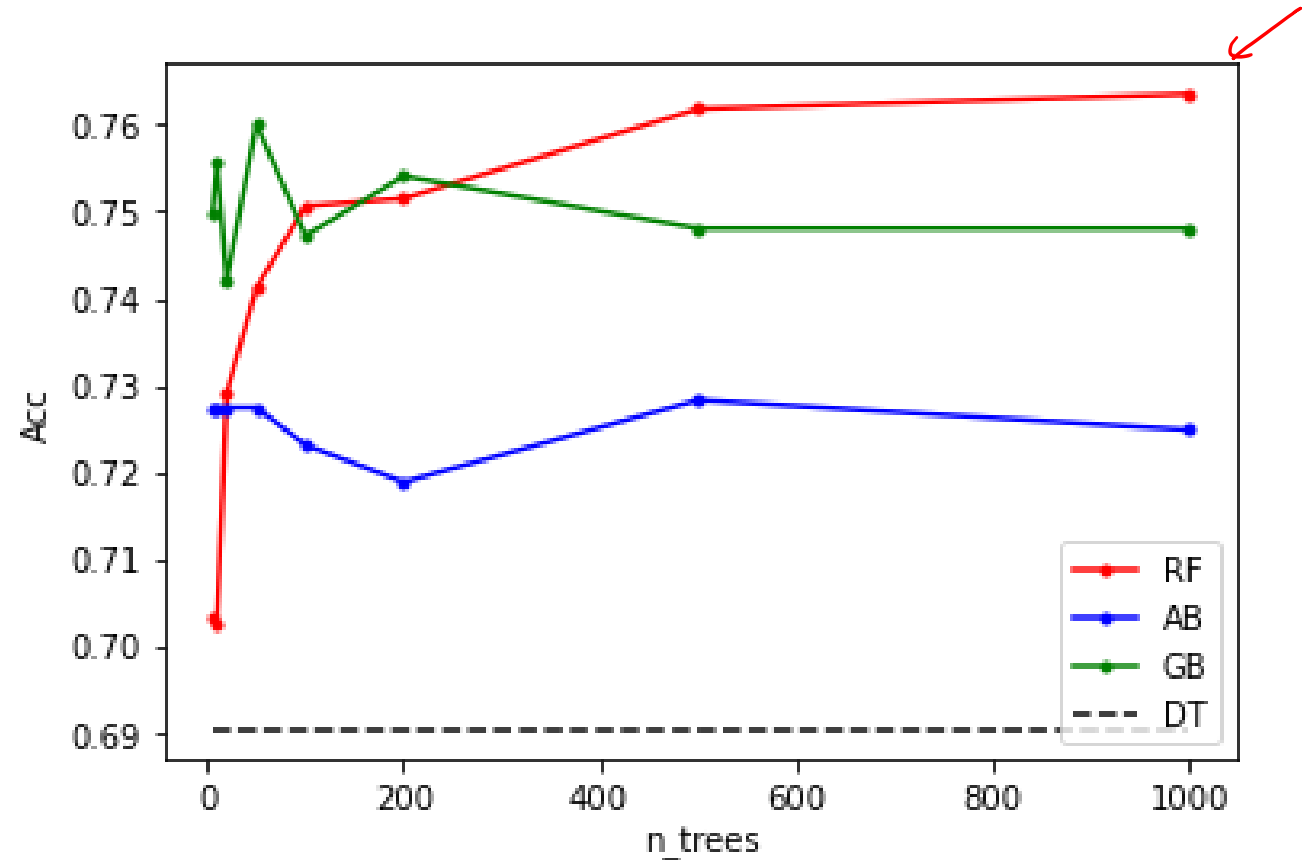
Data 1



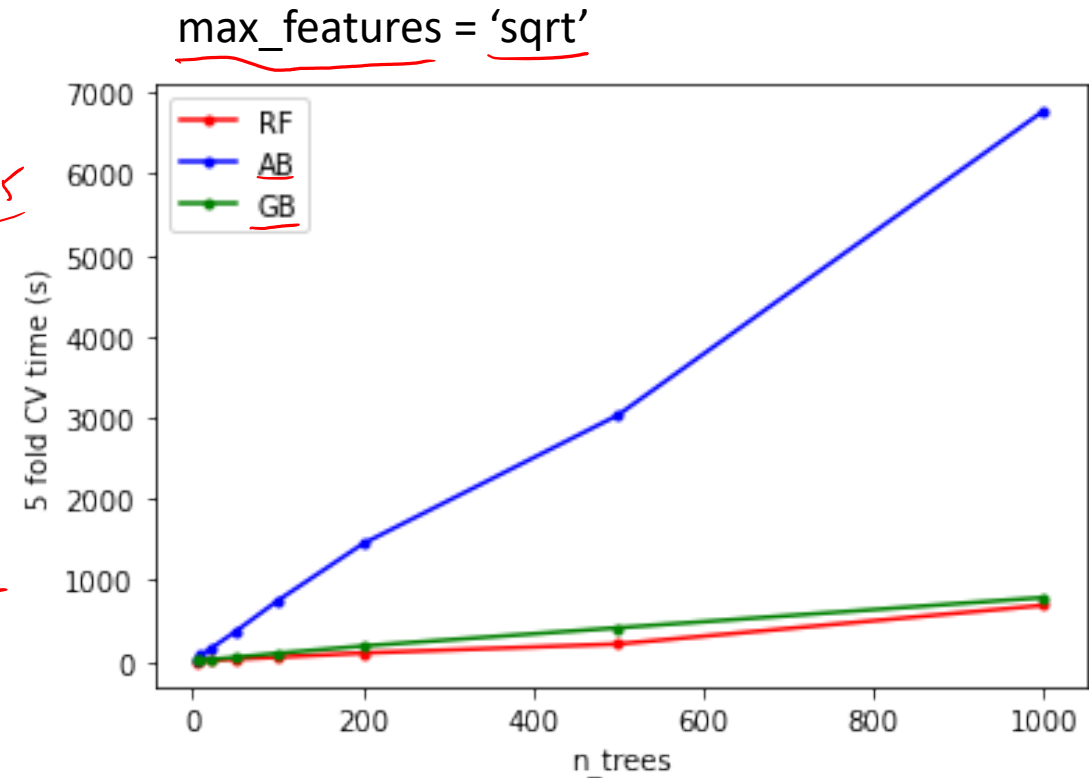
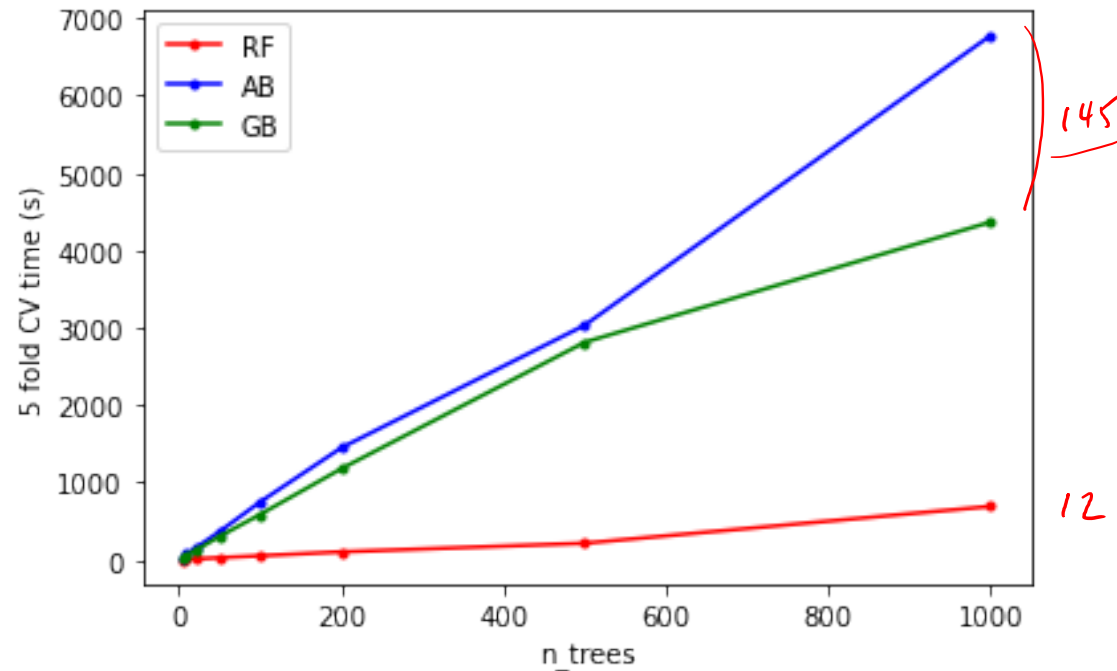
Performance Comparison /w Random Forest

Data 3.

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



Performance Comparison /w Random Forest



Other useful packages

- XGBoost →

- lightGBM (Histogram-based)



- ExtraTree

No bagging ,



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)

$$\frac{f_1 + f_2 + \dots + f_M}{M}$$

M large

vs.

Boosting (serial)

$$f_1 + f_2 + f_3 + \dots = f(x)$$