# Hyperparameter optimization of random forest for effective prediction of water distribution failures

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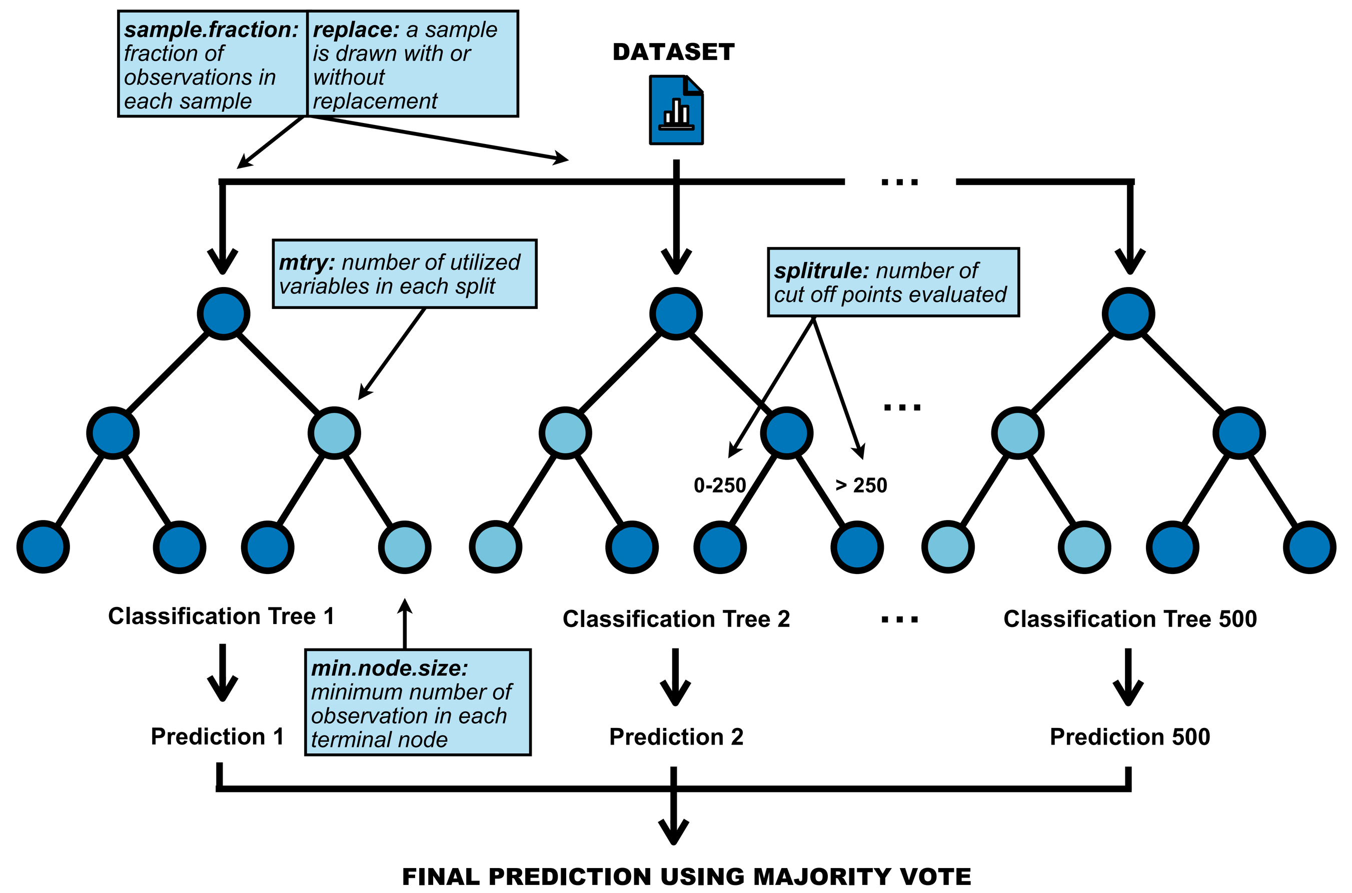
## A WATER DISTRIBUTION SYSTEM IN KENYA

- Western Kenya has a water distribution system of rural pumps that provide clean water to citizens [6].
- Broken pumps prevent entire towns from accessing water.
- Training data with records of 3,934 functioning and 271 non-functioning pumps are available. It has 5 predictors such as number of pumping events, water flow through the pump, and others.

**Goal:** Build a machine learning algorithm to predict pump failures.

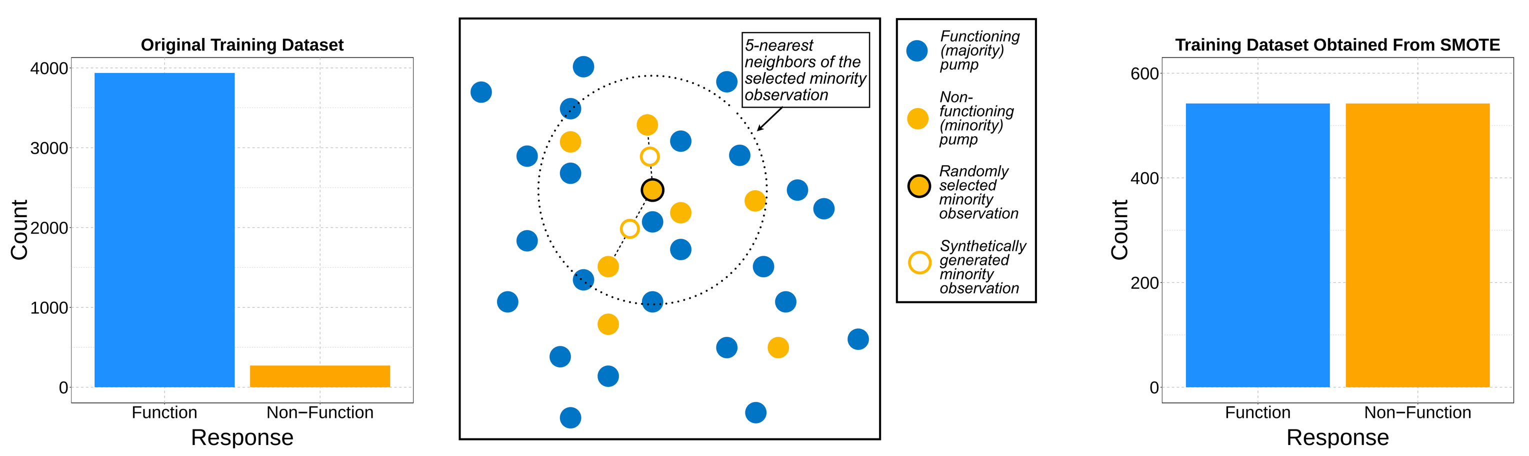
## RANDOM FOREST

Random forest is an ensemble of many classification trees built using random samples of observations and predictors. It has 5 hyperparameters that drive its predictive performance [3, 4].




## SMOTE FOR UNBALANCED DATASETS

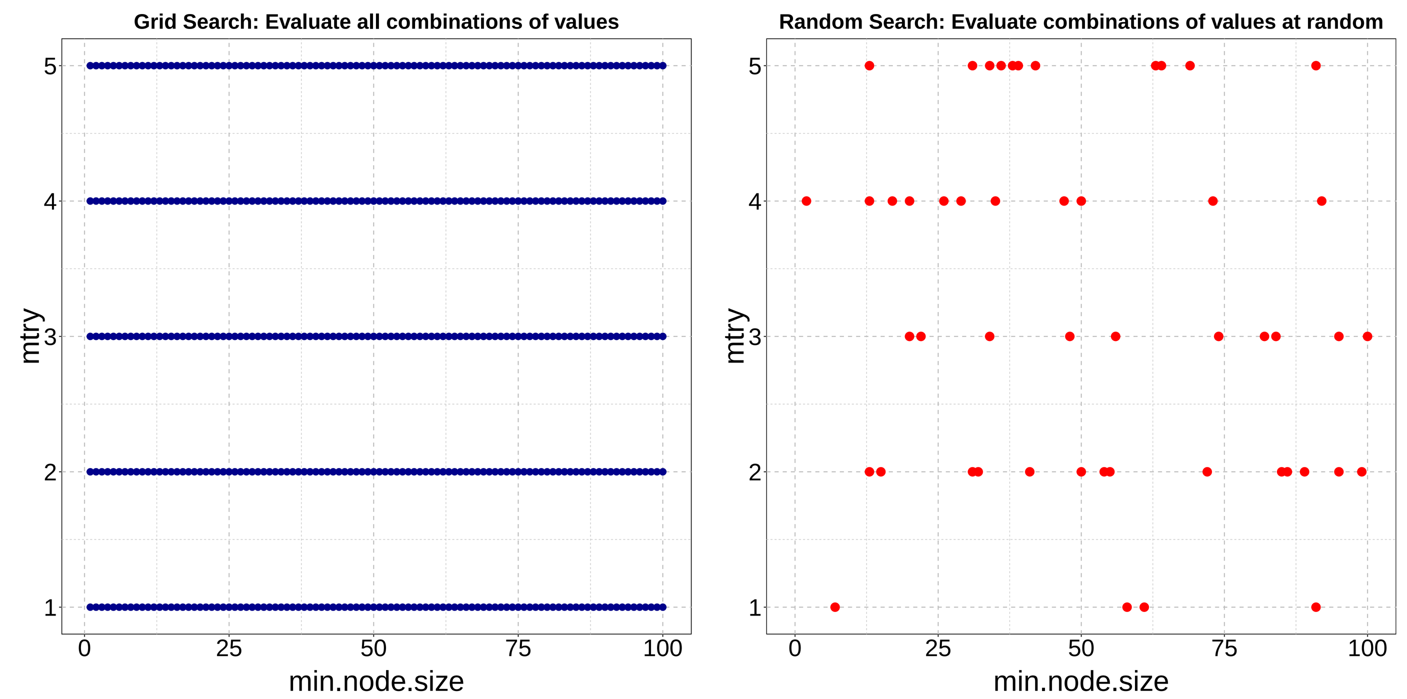
SMOTE is an over-sampling method in which the minority class is over-sampled by creating synthetic examples [2].




## HYPERPARAMETER OPTIMIZATION

**Question:** Can we improve the predictive performance of random forest by selecting good values for its hyperparameters [1]?

**Traditional methods** are grid and random searches, which may be ineffective or expensive for a large number of hyperparameters.

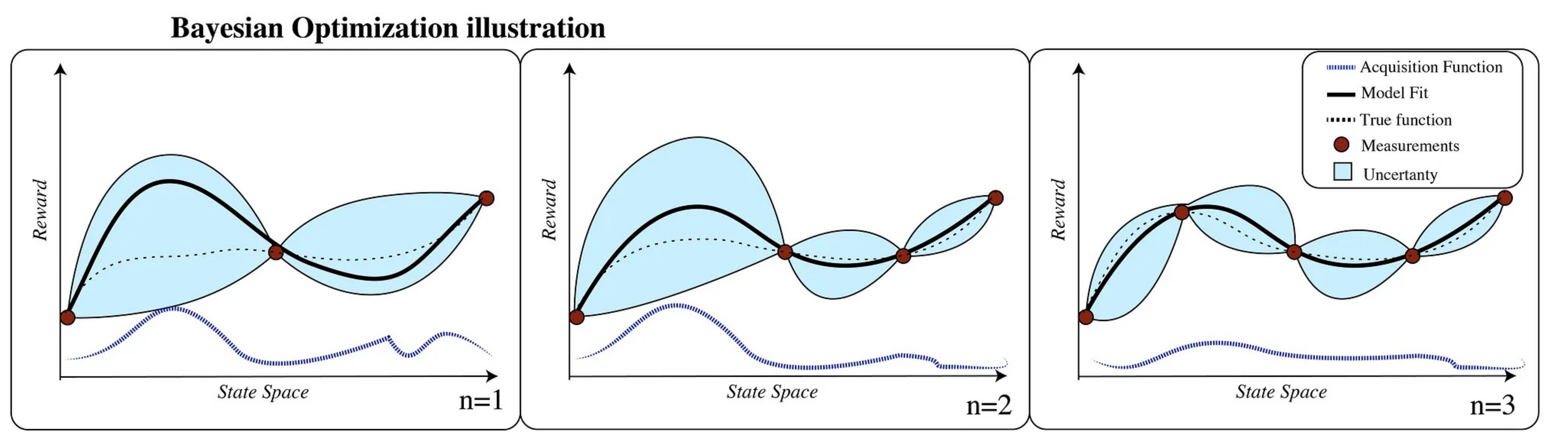



## BAYESIAN OPTIMIZATION

Bayesian Optimization is a global optimization method that is recently being used for hyperparameter optimization [1].

It has 4 steps:

1. Select an initial set of values using random sampling.
2. Fit a surrogate (*Gaussian process*) model that approximates the relation between the predictive performance and hyperparameters.
3. Maximize an acquisition function (*expected improvement*) to find the next combination of values to test.
4. Iterate between 2 and 3 until a maximum number of iterations.




Source: https://towardsdatascience.com/design-optimization-with-ax-in-python-957b1fec776f

## NUMERICAL COMPARISONS

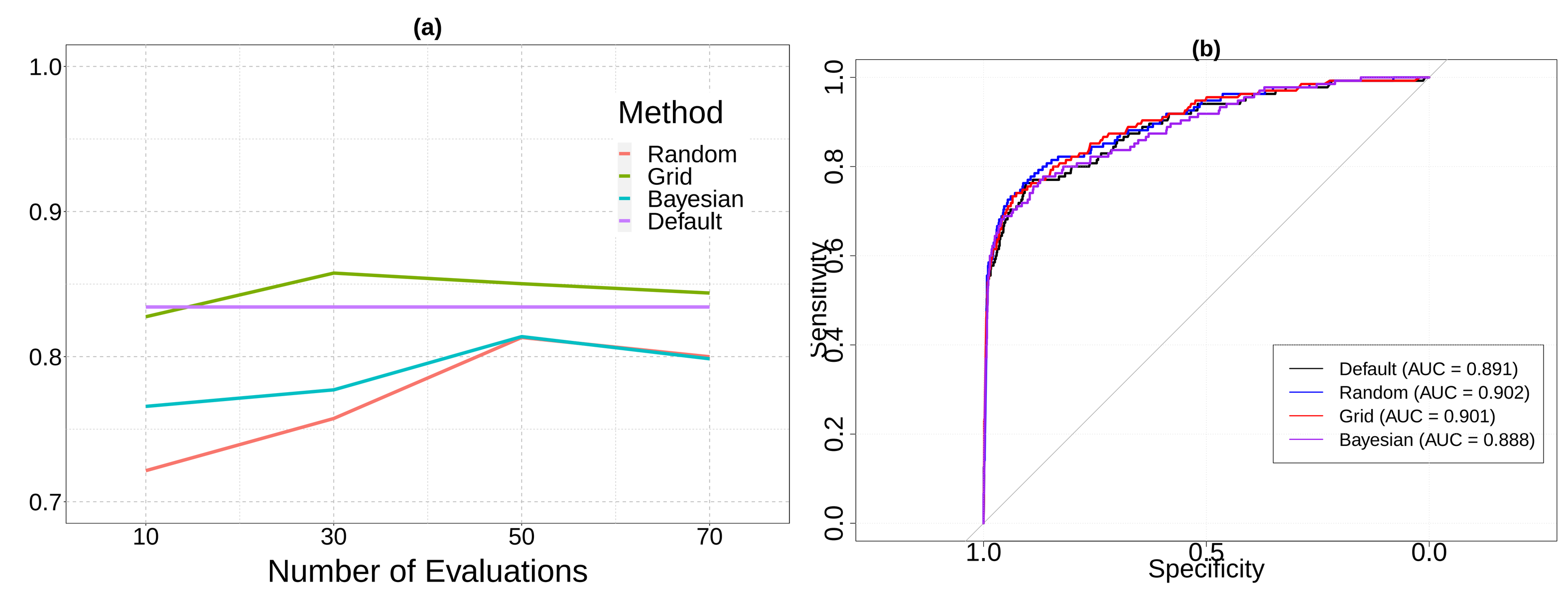
### Performance metrics

- Probability that a non-functioning pump is correctly identified among all non-functioning pumps (***sensitivity***).
- Probability that a functioning pump is correctly identified among all functioning pumps (***specificity***).

### Results

(a) Mean 5-fold cross-validation sensitivity estimate of 5 repetitions.

(b) Sensitivity and specificity obtained from test data with 1,968 functioning and 135 non-functioning pumps.




## DISCUSSION

- Hyperparameter optimization improves random forest.
- However, the improvement is marginal, suggesting that the algorithm is not tunable [5]. Moreover, standard Bayesian Optimization does not outperform the traditional methods.
- The performance of Bayesian Optimization may be improved by tuning its *meta*-hyperparameters, thus hindering the original problem.

**Acknowledgements**

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## References

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