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Parametric and Nonparametric Machine Learning Algorithms

by **Jason Brownlee** on March 14, 2016 in **Machine Learning Algorithms**

What is a parametric machine learning algorithm and how is it different from a nonparametric machine learning algorithm?

In this post you will discover the difference between parametric and nonparametric machine learning algorithms.

Let's get started.

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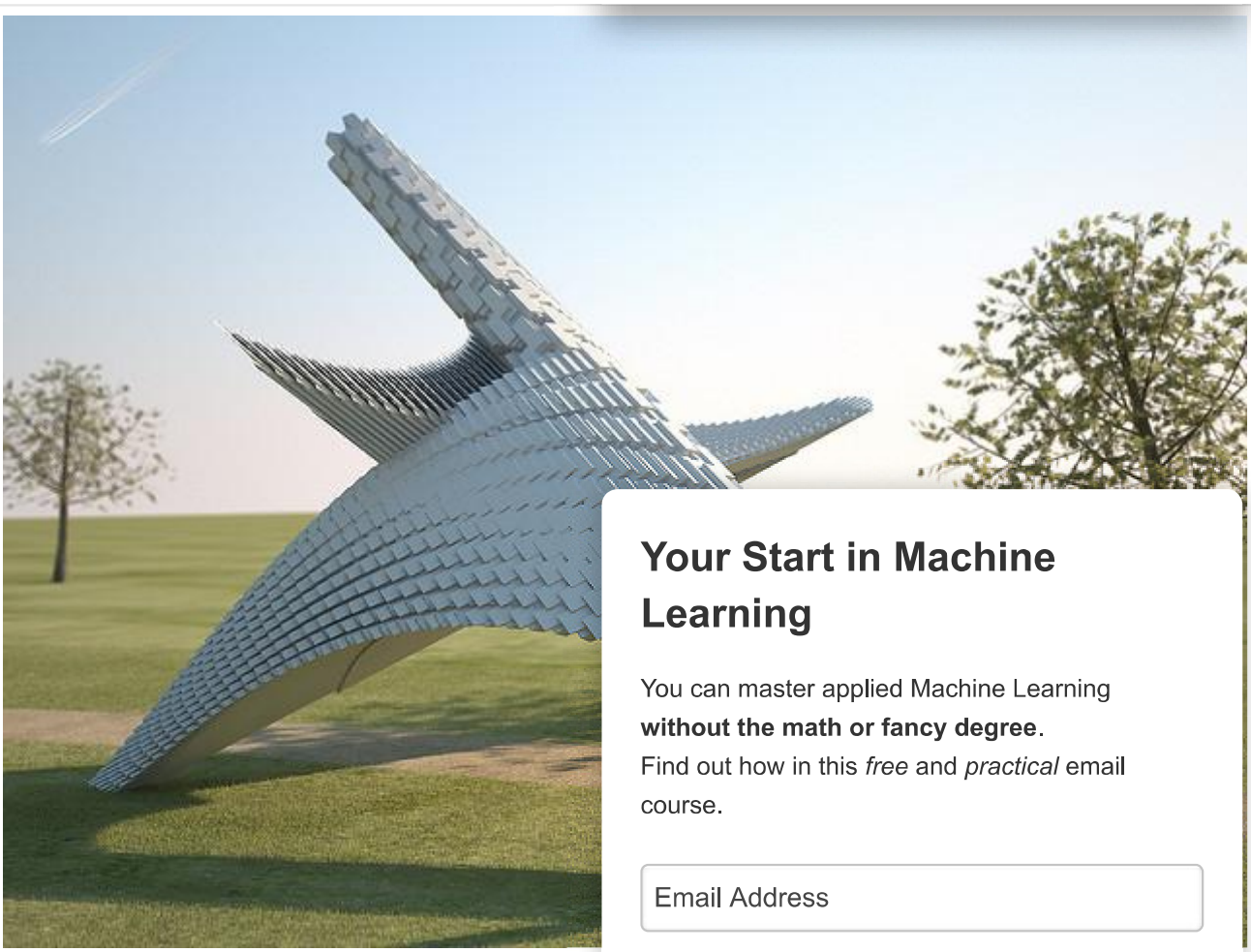

Parametric and Nonparamet
Photo by John M.,

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Learning a Function

Machine learning can be summarized as learning a function (f) that maps input variables (X) to output variables (Y).

$$Y = f(x)$$

An algorithm learns this target mapping function from training data.

The form of the function is unknown, so our job as machine learning practitioners is to evaluate different machine learning algorithms and see which is better at approximating the underlying function.

Different algorithms make different assumptions or biases about the form of the function and how it can be learned.

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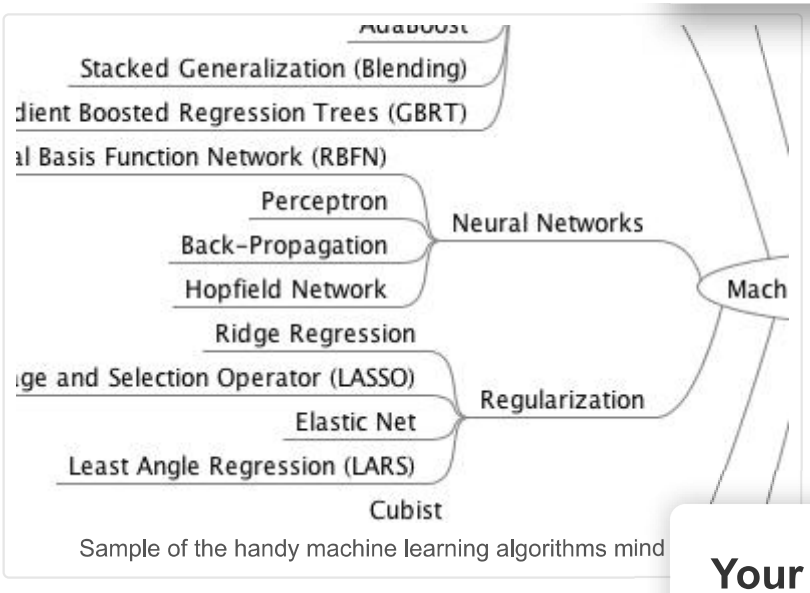

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the function to a known form are called parametric

> *A learning model that summarizes data wit*
> *the number of training examples) is called*
> *throw at a parametric model, it won't chang*

— Artificial Intelligence: A Modern Approach, page

The algorithms involve two steps:

1. Select a form for the function.
2. Learn the coefficients for the function from the training data.

An easy to understand functional form for the mapping function is a line, as is used in linear regression:

$$b0 + b1*x1 + b2*x2 = 0$$

Where b0, b1 and b2 are the coefficients of the line that control the intercept and slope, and x1 and x2 are two input variables.

Assuming the functional form of a line greatly simplifies the learning process. Now, all we need to do is estimate the coefficients of the line equation and we have a predictive model for the problem.

Often the assumed functional form is a linear combination of the input variables and as such parametric machine learning algorithms are often also called "*linear machine learning algorithms*".

The problem is, the actual unknown underlying function may not be a linear function like a line. It could be almost a line and require some minor transformation of the input data to work right. Or it could be nothing like a line in which case the assumption is wrong and the approach will produce poor results.

Some more examples of parametric machine learning algorithms include:

- Logistic Regression
- Linear Discriminant Analysis

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- Perceptron
- Naive Bayes
- Simple Neural Networks

Benefits of Parametric Machine Learning Algorithms:

- **Simpler**: These methods are easier to understand and interpret results.
- **Speed**: Parametric models are very fast to learn from data.
- **Less Data**: They do not require as much training data and can work well even if the fit to the data is not perfect.

Limitations of Parametric Machine Learning Algorithms:

- **Constrained**: By choosing a functional form th ied form.
- **Limited Complexity**: The methods are more
- **Poor Fit**: In practice the methods are unlikely

Nonparametric Machine Learn

Algorithms that do not make strong assumptions a nonparametric machine learning algorithms. By no functional form from the training data.

> *Nonparametric methods are good when yo when you don't want to worry too much abo*

— Artificial Intelligence: A Modern Approach, page 757

Nonparametric methods seek to best fit the training data in constructing the mapping function, whilst maintaining some ability to generalize to unseen data. As such, they are able to fit a large number of functional forms.

An easy to understand nonparametric model is the k-nearest neighbors algorithm that makes predictions based on the k most similar training patterns for a new data instance. The method does not assume anything about the form of the mapping function other than patterns that are close are likely have a similar output variable.

Some more examples of popular nonparametric machine learning algorithms are:

- k-Nearest Neighbors
- Decision Trees like CART and C4.5
- Support Vector Machines

Benefits of Nonparametric Machine Learning Algorithms:

- **Flexibility**: Capable of fitting a large number of functional forms.
- **Power**: No assumptions (or weak assumptions) about the underlying function
- **Performance**: Can result in higher performan

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Limitations of Nonparametric Machine Learning Algorithms:

- **More data**: Require a lot more training data to estimate the mapping function.
- **Slower**: A lot slower to train as they often have far more parameters to train.
- **Overfitting**: More of a risk to overfit the training data and it is harder to explain why specific predictions are made.

Further Reading

This section lists some resources if you are looking to learn more about the difference between parametric and non-parametric machine learning algorithms.

Books

- An Introduction to Statistical Learning: with Ap
- Artificial Intelligence: A Modern Approach, cha

Posts

- What are the advantages of using non-parame
- What are the disadvantages of non-parametri
- Nonparametric statistics on Wikipedia
- Parametric statistics on Wikipedia
- Parametric vs. Nonparametric on Stack Excha

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Summary

In this post you have discovered the difference between parametric and nonparametric machine learning algorithms.

You learned that parametric methods make large assumptions about the mapping of the input variables to the output variable and in turn are faster to train, require less data but may not be as powerful.

You also learned that nonparametric methods make few or no assumptions about the target function and in turn require a lot more data, are slower to train and have a higher model complexity but can result in more powerful models.

If you have any questions about parametric or nonparametric machine learning algorithms or this post, leave a comment and I will do my best to answer them.

Update: I originally had some algorithms listed under the wrong sections like neural nets and naive bayes, which made things confusing. All fixed now.

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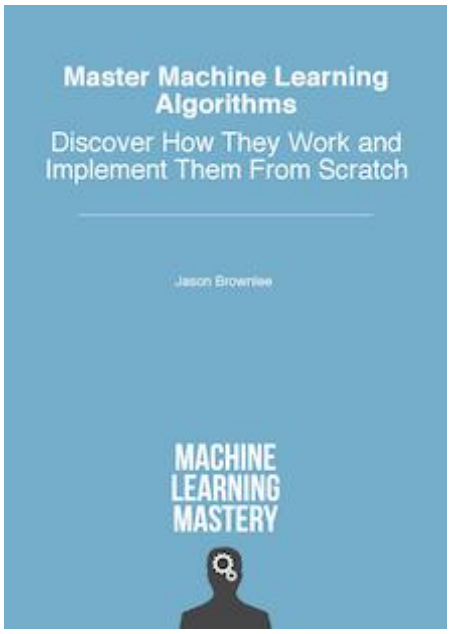

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About Jason Brownlee

Jason Brownlee, Ph.D. is a machine le
results with modern machine learning r
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‹ How Machine Learning Algorithms Work (they learn a mapping of input to output)

Supervised and Unsupervised Machine Learning Algorithms ›

33 Responses to *Parametric and Nonparametric Machine Learning Algorithms*

confused beginner March 14, 2016 at 6:02 pm #

REPLY

hi jason

thanks for taking your time to summarize these topics so that even a novice like me can understand. love your posts

i have a problem with this article though, according to the small amount of knowledge i have on parametric/non parametric models, non parametric models are models that need to keep the whole data set around to make future predictions. and it looks like Artificial Intelligence: A Modern Approach, chapter

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18 agrees with me on this fact stating neural nets are parametric and once the weights w are learnt we can get rid of the training set. i would say its the same case with trees/naive bays as well.

so what was your thinking behind in categorizing these methods as non-parametric?

thanks,
a confused beginner

Jason Brownlee July 17, 2016 at 6:57 am #

REPLY

Indeed simple multilayer perceptron neural nets are parametric models.

Non-parametric models do not need to keep th
parametric algorithm is kNN that does keep the
vary the number of parameters, like the numbe
vectors, etc.

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mlvi July 27, 2017 at 1:49 am #

Isn't number of nodes in the decis

One more question is, How do you deploy
production as there parameters are not fixe

Jason Brownlee July 27, 2017 at 8:10 am #

REPLY

No, but the max depth of the tree is.

You can finalize your model, save it to file and load it later to make predictions on new data.

See this post:
http://machinelearningmastery.com/train-final-machine-learning-model/

Does that help?

Another confused beginner March 15, 2016 at 3:13 am #

REPLY

I am also interesting to know why Naive Bayes is categorized as non-parametric.

Jason Brownlee July 17, 2016 at 7:06 am #

REPLY

Yes, Naive bayes is generally a parametric method as we choose a distribution (Gaussian) for the input variables, although there are non-parametric formulations of the method that use a kernel estimator. In fact, these may be more cc

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Ecolss March 15, 2016 at 5:41 pm #

REPLY

Confused here too.

AFAIK, parametric models have fixed parameter set, i.e. the amount of parameters won't change once you have designed the model, whereas the amount of parameters of non-parametric models varies, for example, Gaussian Process and matrix factorization for collaborative filtering etc.

Correct me if I'm wrong 🙂

Jason Brownlee July 17, 2016 at 7:06 ar

This is correct.

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Simon Tse July 16, 2016 at 10:21 pm #

I think the classification does not really de
assumption you have made when you try to constr
has a probability model (i.e. pdf) behind to support
distribution or other distribution model.

On the other hand, non-parametric model just depe
identify the set of 'parameters' which has nothing to do with a pdf.

So, parameters are still there for both parametric and non-parametric ML algo. It just doesn't have additional layer of assumption to govern the nature of pdf of which the ML algo tries to determine.

Jason Brownlee July 17, 2016 at 7:10 am #

REPLY

Hi Simon, the statistical definition of parametric and non-parametric does not agree with you.

The crux of the definition is whether the number of parameters is fixed or not.

It might be more helpful for us to consider linear and non-linear methods instead…

Kevin August 11, 2016 at 1:11 pm #

REPLY

Is there a relation between parametric/nonparametric models and lazy/eager learning?

ANUDEEP VANJAVAKAM September

REPLY

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In machine learning literature, nonparametric methods are also call instance-based or memory-based learning algorithms.
-Store the training instances in a lookup table and interpolate from these for prediction.
-Lazy learning algorithm, as opposed to the eager parametric methods, which have simple model and a small number of parameters, and once parameters are learned we no longer keep the training set.

Jianye September 27, 2016 at 11:18 am #

REPLY

I have questions of distinguishing betwee
linear regression, we can also introducing x^2, x^3
it mean that it becomes non parametric in this case

2) The main difference between them is that SVM
hyperplane . Why perception is considered as para

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Jason Brownlee September 28, 2016 at

Hi Jianye,

When it comes down to it, parametric means a
modeled decision.

Adding more inputs makes the linear regression equation still parametric.

SVM can choose the number of support vectors based on the data and hyperparameter tuning, making it non-parametric.

I hope that is clearer.

Pramit Choudhary January 23, 2017 at 1:09 pm #

REPLY

Hi Jason,
Nice content here. Had some suggestions,
1. Do you think, it would be a good idea to include histogram: as a simple non-parametric model for estimation probability distribution ? Some beginners might be able to related to histograms.
2. Also, may be mentioning SVM(RBF kernel) as non-parametric to be precise.
What do you think ?

Jason Brownlee January 24, 2017 at 10:54 am #

REPLY

Hi Pramit,

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1. nice suggestion.
2. perhaps, there is debate about where SVM sits. I do think it is nonparametric as the number of support vectors is chosen based on the data and the interaction with the argument-defined margin.

Manish Barnwal March 30, 2017 at 8:50 pm #

REPLY

Jason, as always, an excellent post.

Jason Brownlee March 31, 2017 at 5:54

REPLY

Thanks Manish.

amr gamal April 12, 2017 at 1:40 am #

jason ,it is a good post about parametric a
but i still confused
did deep learning supposed to be parametric or no
Best Regards

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Jason Brownlee April 12, 2017 at 7:55 am #

REPLY

There is not a hard line between parametric and non-parametric.

I think of neural nets as non-parametric myself.

See this:
https://www.quora.com/Are-Neural-Networks-parametric-or-non-parametric-models

Aishwarya May 4, 2017 at 8:10 am #

REPLY

Hi
The answer is very convincing, i just have a small question, for pressure distribution plots which ML algorithm should we consider?

Jason Brownlee May 5, 2017 at 7:26 am #

REPLY

Sorry, I don't know what pressure distribution plots are.

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Sanket Maheshwari May 17, 2017 at 7:45 am #

REPLY

Hi Jason,

Decision tree contains parameters like Splitting Criteria, Minimal Size, Minimal Leaf Size, Minimal Gain, Maximal Depth then why it is called as non-parametric. Please throw some light on it.

Jason Brownlee May 17, 2017 at 8:45 am #

REPLY

They are considered hyperparameters of the model.

The chosen split points are the parameters of t
specific data. Thus, the decision tree is a nonp

Does that make sense?

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Sanket Maheshwari May 18, 2017 at 7:37 pr

Could you please briefly tell me what are t
models:

1.Naive Baye
2.KNN
3.Decision Tree
4.Multiple Regression
5.Logistic Regression

Jason Brownlee May 19, 2017 at 8:16 am #

REPLY

Yes, please search the blog for posts on each of these algorithms.

Guiferviz November 3, 2017 at 10:45 pm #

REPLY

Hi Jason! Nice blog.

I have a doubt about the “simple neural networks”, shouldn’t it be “neural networks” in general? The number of parameters is determined a priori.

In addition, I think that linear SVM might be considered as a parametric model because, despite the number of support vector varies with the data, the final decision boundary can be expressed as a fixed number of parameters.

I know the distinction between parametric and non-parametric is a little bit ambiguous, but what I said makes sense, right?

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duribef May 12, 2018 at 4:06 am #

REPLY

Up to this question! I have the same doubt about linear SVM.

Saludos!

Aniket Saxena November 7, 2017 at 3:25 am #

REPLY

Hi Jason, I want to know that despite having not required much data to train, does the parametric algorithms also cause overfitting? Or can they be lead to underfitting, instead?

Jason Brownlee November 7, 2017 at 9:

Both types of algorithms can over and

It is more common that parametric underfit and

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Aniket Saxena November 8, 2017 at 12:20 am

Hi Jason, thanks for your help but there is

above my question because it is a nice question about distinction between parametric vs non-parametric and I am very curious to know your opinion about this question posted by Guiferviz on november 3, 2017. Please answer to this question…….

Magnus January 31, 2018 at 9:10 pm #

REPLY

Hi Jason, you mention that simple multilayer perceptron neural nets are parametric models. This I understand, but which neural networks are then non-parametric? I assume e.g. that neural nets with dropouts are non-parametric?

Jason Brownlee February 1, 2018 at 7:19 am #

REPLY

Perhaps. Categorizing algorithms gets messy.

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Name (required)

Email (will not be published)

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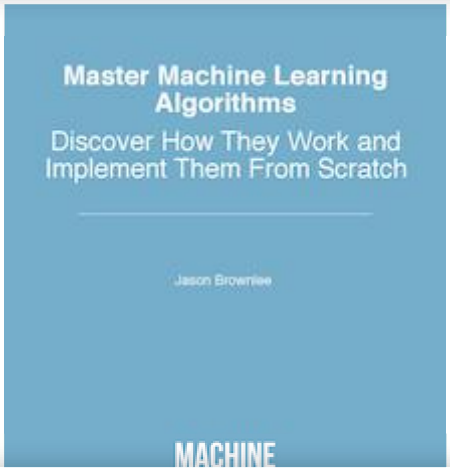

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