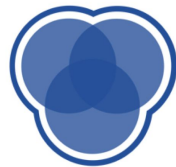


INFO 1998: Introduction to Machine Learning



CDS Education

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Lecture 4: Fundamentals of Machine Learning Pt. 1

INFO 1998: Introduction to Machine Learning

Introduction to Machine Learning and Tools



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Project

- Start thinking about what datasets and questions you want to explore
- If you still need a partner, post on Ed or stay after class
- Rubric can be found on our website under “Final Project”



Project Check-in

- We'll have a check-in in about 2-3 weeks.
 - Expecting hypothesis/question/problem to solve
 - Chosen dataset
 - Some progress on data cleaning/data visualization
- Come to OH if you need help or if there's a problem



What We'll Cover

Today's Goal: be able to write code to do some kind of ML (to some extent)

- **Define Machine Learning:** or like, 5 definitions
- **Start learning the language of ML:** There's a lot of terminology :(
- **Try Linear Regression (via ScikitLearn):** Our first ML algorithm!
- **Introduce our Workflow:** An outline for developing an ML model
- **Discuss Some Important Considerations:** What should we be thinking about as we're MLing?



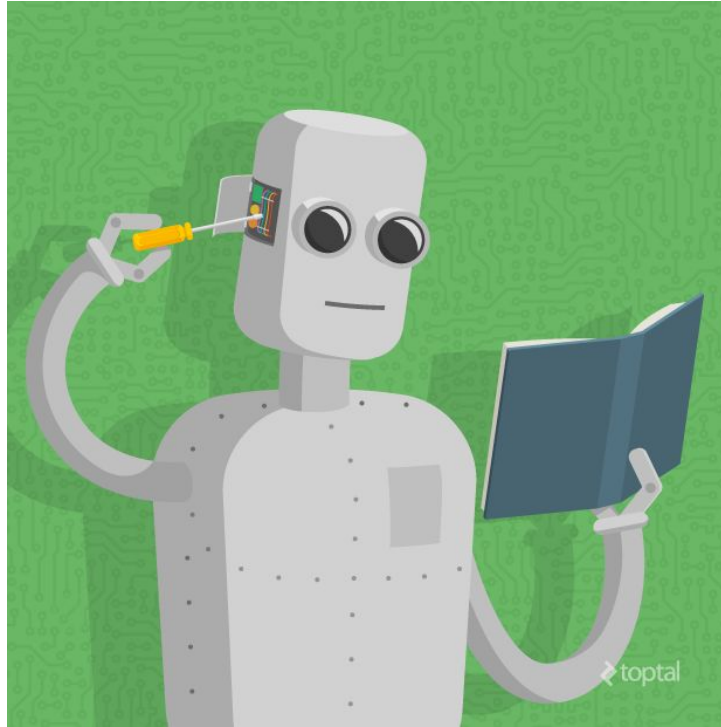
Agenda

1. What does a Machine Learning Engineer do?
2. On a high level, how do you define “Machine Learning”?
3. What’s a Machine Learning Model?
4. What’s a *good* Machine Learning Model?



What's Machine Learning?

Part 1: what does an ML engineer do



Machine Learning can involve:

- Preprocessing data
- Splitting and selecting pieces of data
- Doing mathematical analysis on the data
- Deciding what data structures are needed to efficiently implement algorithms
- Manipulating those data structures as the algorithm indicates
- Optimizing for hardware infrastructure
- Implementing accuracy metrics
- ...and a lot more



How do we do machine learning?



What we're gonna do:

Write as little code as possible!

- Use pandas to deal with data
- Use numpy to do math
- Use scikit-learn (“sklearn”) to make ML models (and other useful stuff)



What we're gonna do:

Our main tasks:

- Choose an algorithm
- Choose how to use different parts of the data
- Find which pandas, numpy, and scikit-learn functions do what we want
- Interpret the results and fine-tune our model



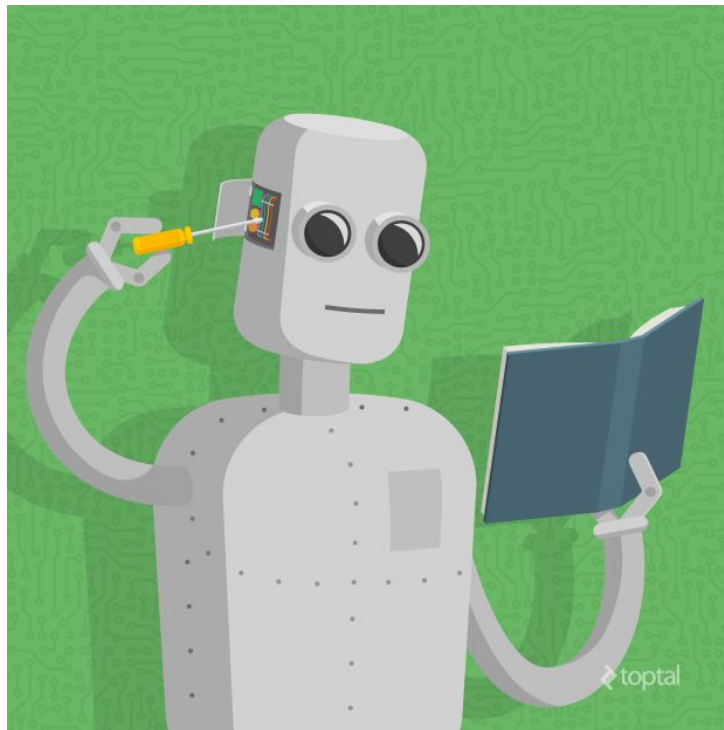
Quick analogy: studying

- Setup
 - Goal: Be able to solve the test problems
 - Resources: Practice problems + answers
- Method
 - You study those practice problems and answers. Given a problem, how do you get the answer?
- Result:
 - On the real test, the problems aren't the exact same as the practice problems. But they're similar!
 - Since you learned generally how to solve the practice problems, you can solve the similar test problems too :)



What's Machine Learning?

Part 2: like seriously what is it

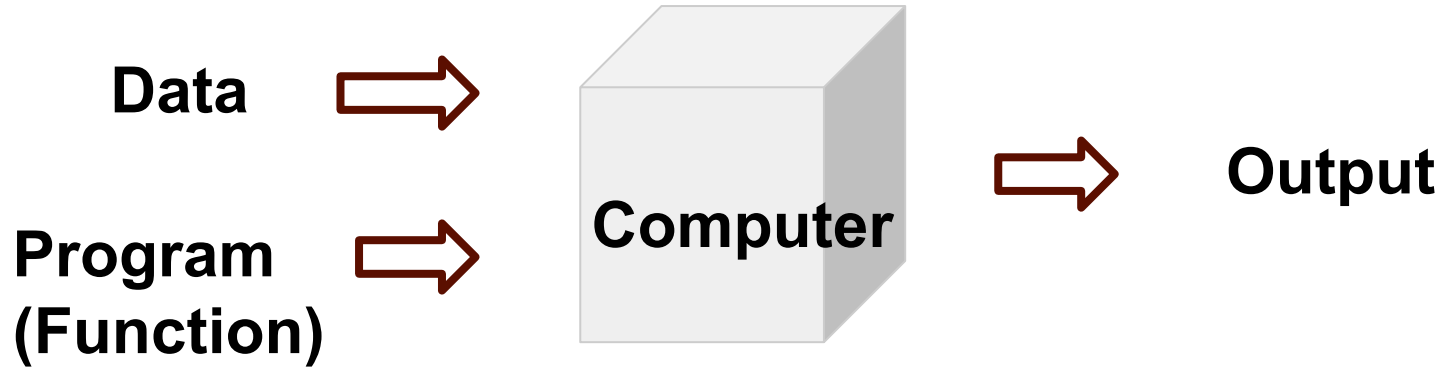


Some Definitions of ML

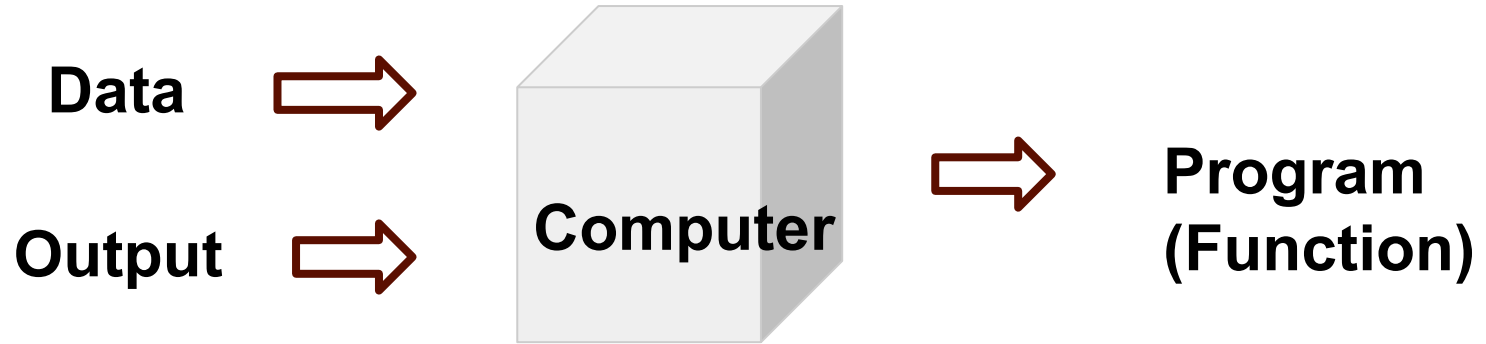
- Give computers the ability to learn without being explicitly programmed
(^ *that one's a pretty sucky definition*)
- Build a useful mathematical model, based on sample data, to make inferences
- Take in data and make predictions or decisions
- Help your computer learn patterns



Traditional Computer Science

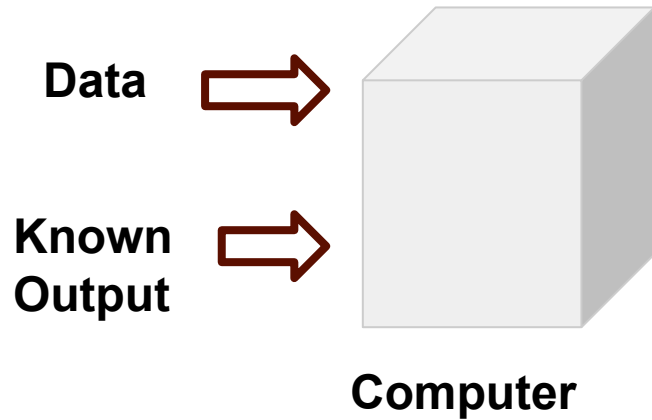


Machine Learning

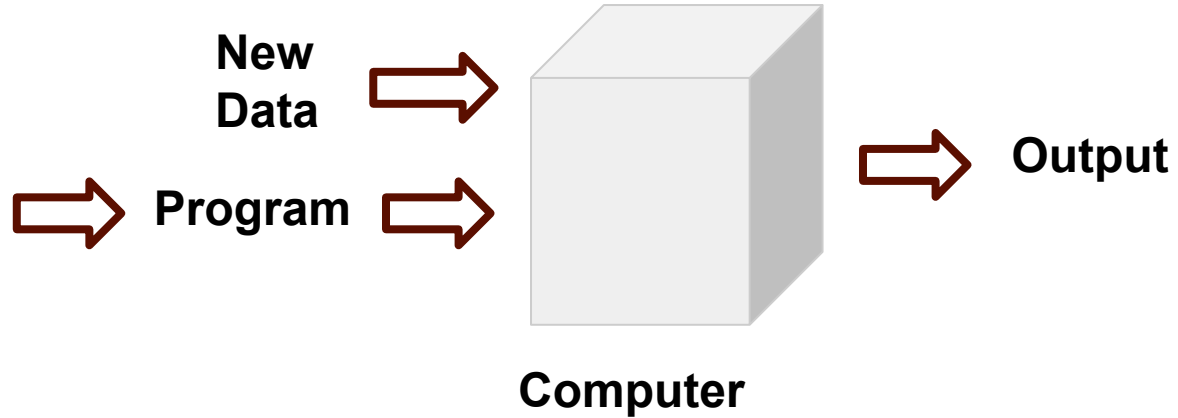


Using Machine Learning

Machine Learning

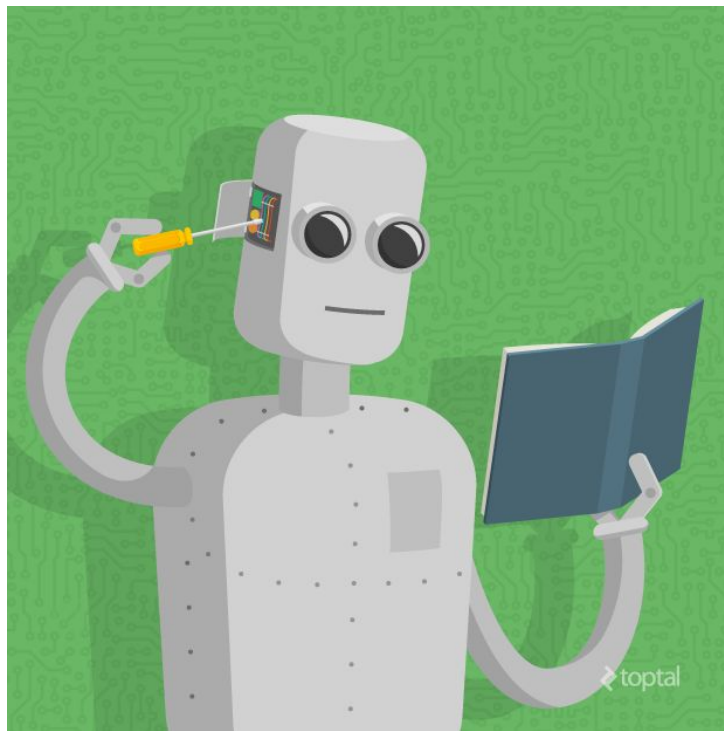


Traditional CS



What's Machine Learning?

Part 3: what's a model?

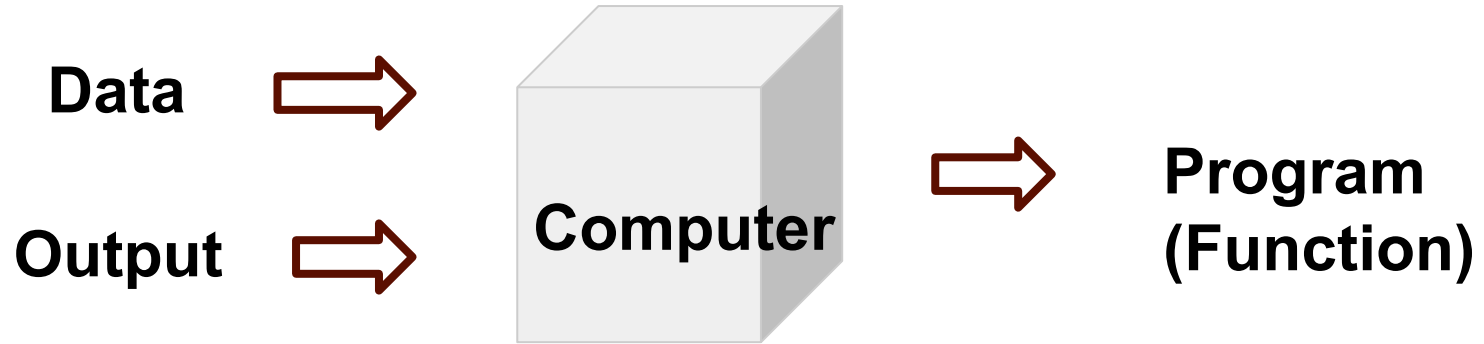


What's a model?

- The output of a machine learning algorithm
- A procedure to produce some outputs when given some inputs
- A relationship between inputs and outputs
- A guess at how inputs and outputs are related
- A set of assumptions we're imposing on the dataset
- A configurable thing (hyperparameters)



ML Algorithm produces a Model



Review: Dataset Structure

- rows are data points
 - aka samples
- columns are features
 - a sample is made of lots of features, including the goal

	Name	Age	Major
0	Ann	19	Computer Science
1	Chris	20	Sociology
2	Dylan	19	Computer Science
3	Camilo	NaN	NaN
4	Tanmay	NaN	NaN



Linear Regression

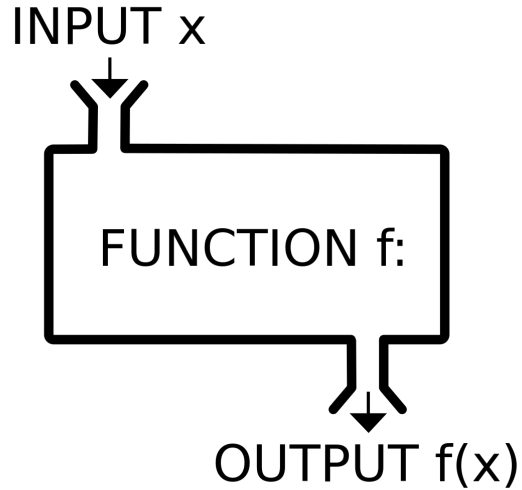
$$y = B_0 + B_1x_1 + \dots + B_px_p + \varepsilon$$

- x is an input; x_1, x_2, \dots, x_p are the features of x
- y is an output (usually a single value)
- B 's are “weights”
 - A linear regression equation is defined by its B 's
 - This linear regression equation is the “program” produced by ML
- Given a set of x 's and y 's, the program finds a set of B 's that (almost) satisfy make the equation above for all x 's and y 's
 - Then, you can plug in the feature values of a new x and to predict its y



Linear Regression

Function



Weighted Sum

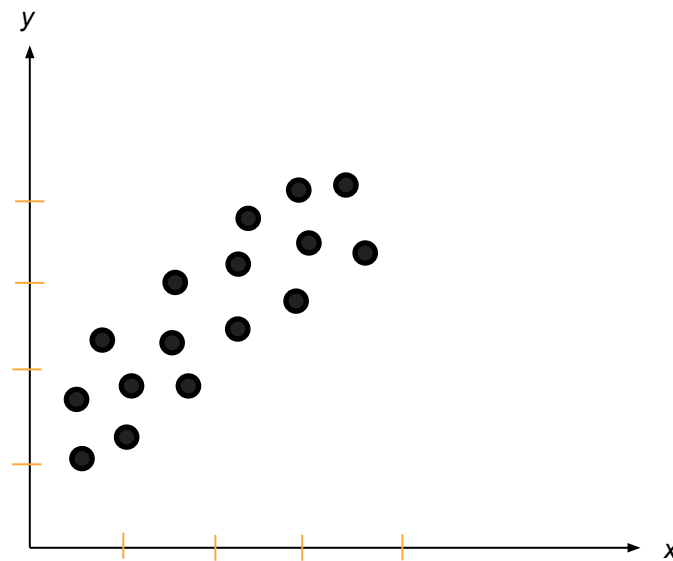
$$x_1 \dots x_p$$

$$y = B_0 + B_1 x_1 + \dots + B_p x_p$$

$$y$$

$y = B_0 + B_1x_1 + \dots$ is a model

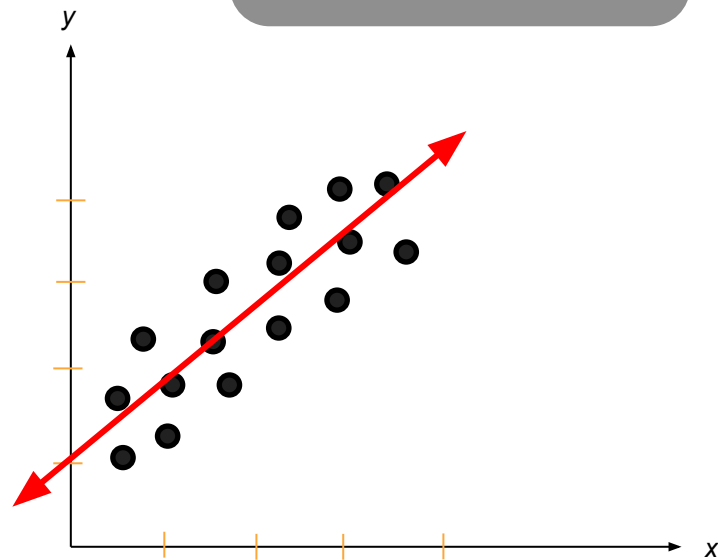
- A relationship between inputs and outputs
 $y = B_0 + B_1x_1 + \dots$ relates inputs to outputs
- A guess at how inputs and outputs are related
but $y = B_0 + B_1x_1 + \dots$ is just a guess/estimate; it's not exactly true
- A set of assumptions we're imposing on the dataset
We're assuming output is linear with input features and input features are ordered
- A configurable thing (hyperparameters)
Sorry, we don't cover very much linear regression configuration here :(



$y = B_0 + B_1x_1 + \dots$ **is a model**

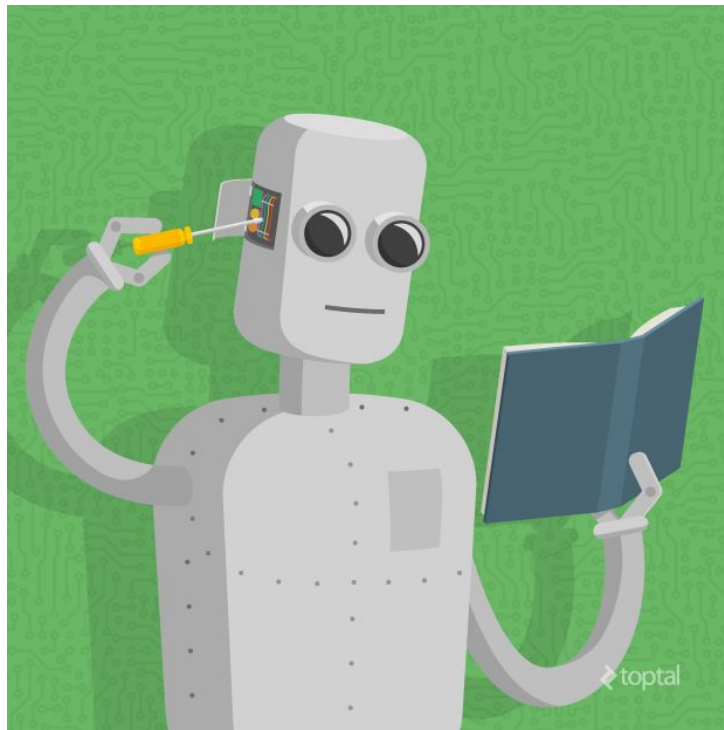
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Use algorithm to “learn” parameters that give us this line of best fit

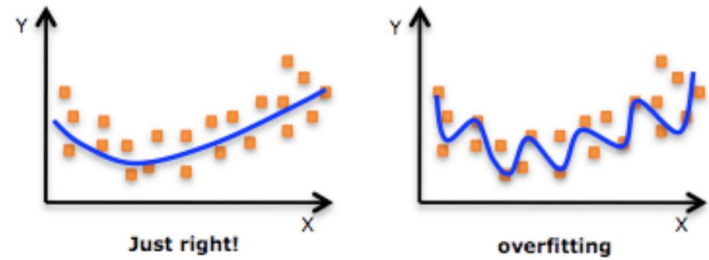


What's Machine Learning?

Part 4: What makes a *good* model?



Pitfall of training: Overfitting



Model is accurate for **train** data



Model can accurately predict **new** data

- We didn't learn the data's general patterns :(
- We learned the specific mapping from **train input to train outputs** :(((

Solution: train on part of data, and check accuracy on a separate part of data (*validation* set)



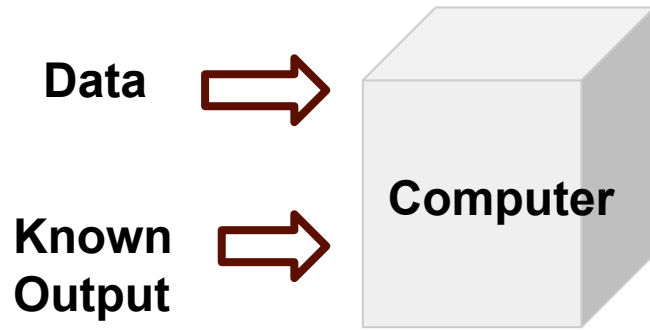
Terminology: Training and Validating

- Split data into two sets
- Train model on one, validate on the other
- “Model training” = learn a relationship/program
 - e.g. give the linear regression data so it can define the B 's
- “Model validation” = see if the learned relationship is accurate on other data

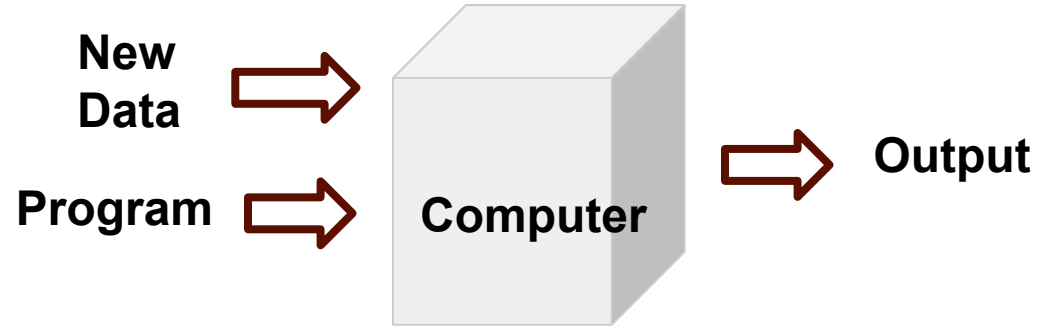


Machine Learning

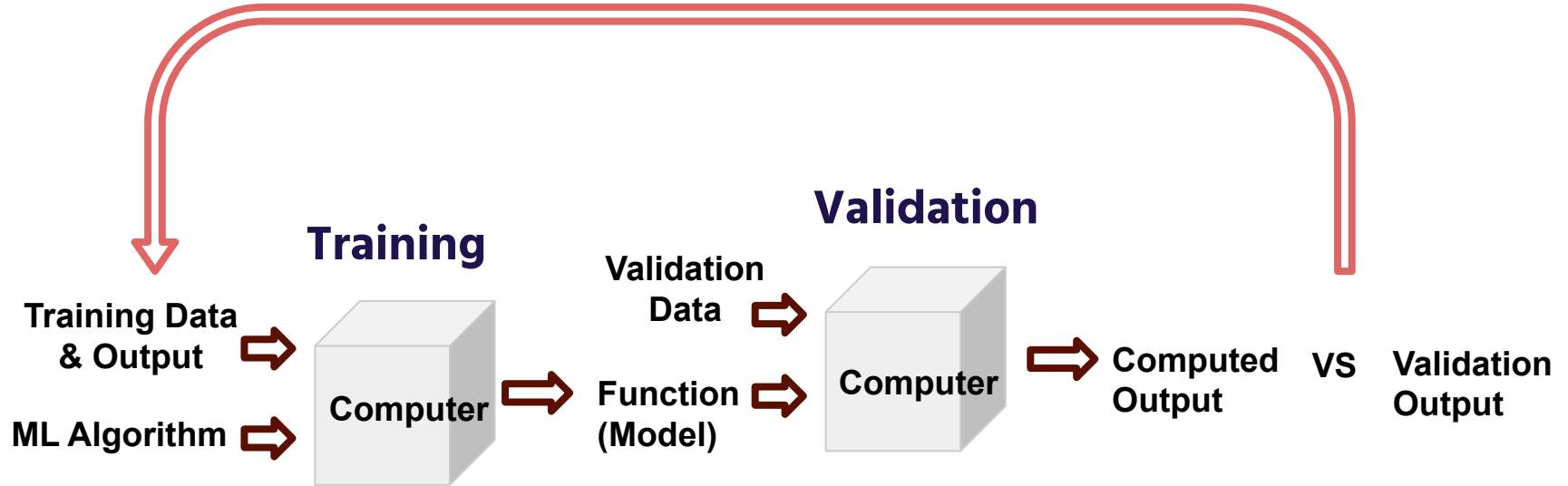
Machine Learning

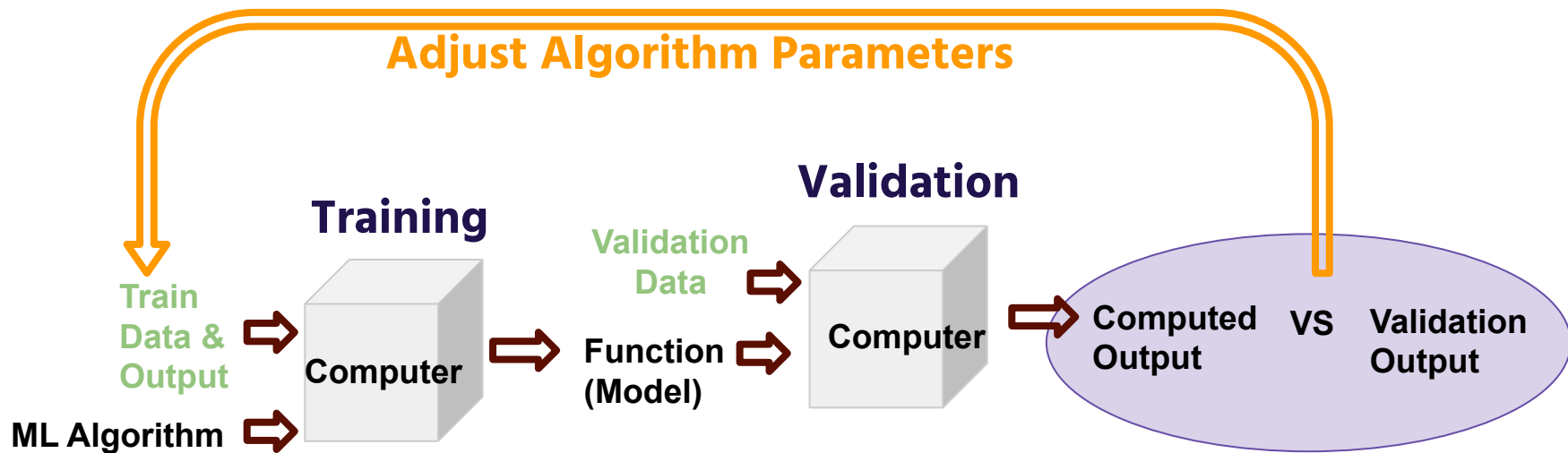


Traditional CS



Our ML Workflow





1. Select data
2. Assess model accuracy
3. Adjust Model



Pitfall of validation: Overfitting

Predicting well on validation set

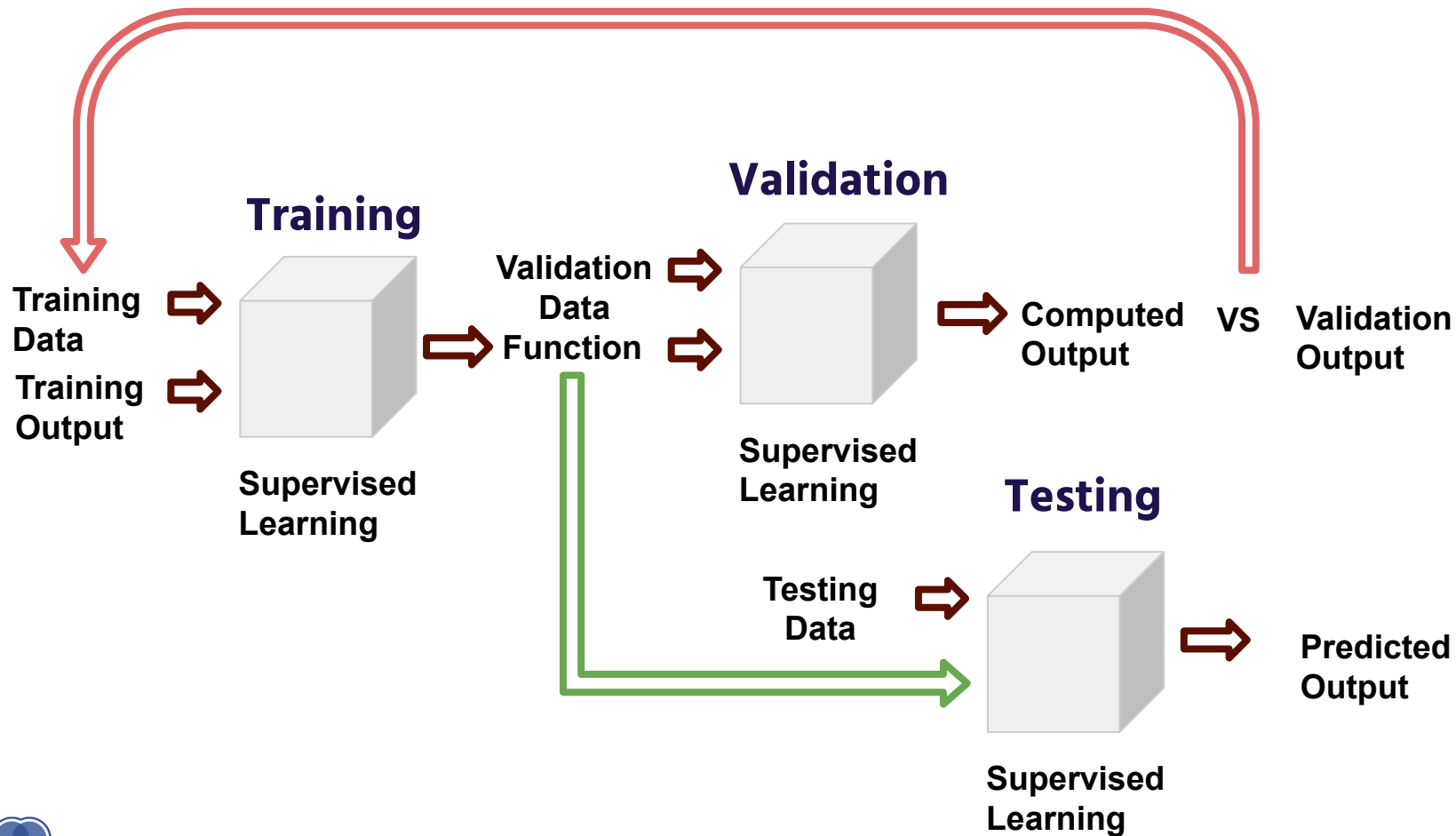


Predicting well on new data

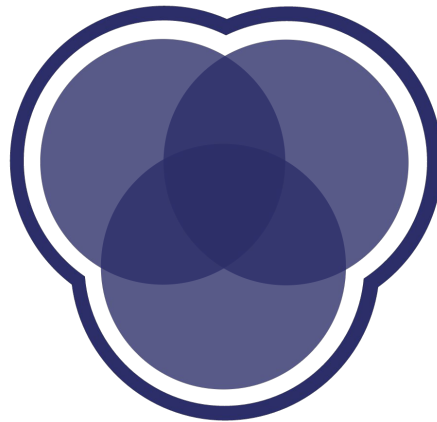
- We used the validation set to make our adjustments. This means our model is **biased** to the validation set 😞

Solution: keep a separate, rarely-used **test** set





Demo



Model Goals

When training a model we want our models to:

- Capture the trends of the training data
- Generalize well to other samples of the population
- Be moderately interpretable

The first two are especially difficult to do simultaneously!
The more sensitive the model, the less generalizable and vice versa.



Putting things into perspective

- Linear Regression alone is weak, but it can be very strong when combined with feature selection and feature engineering
- Linear Regression is just one algorithm — we'll cover many more
- The “model” produced by an algorithm is not always a simple equation like in linear regression
- Validation is really important
 - Overfitting is a huge problem!
 - We'll delve deeper in the next few lectures



Workshop

- Web Scraping workshop!
- 3:30-4:30 Saturday, Upson 152



Coming Up

Assignment 4: Due at 4:30pm EST on 10/20, 2021

Next Lecture: Assessing Model Accuracy + Fundamentals of ML

(a.k.a. *What's Machine Learning? Part ∞*)



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