

Machine Learning From Scratch

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April 25th, 2018

Make sure that everyone launches binder or colab.google first!!

Also, give them a walkthrough of the whole presentation and tell them what we'll be building and what we'll be predicting!

- * we'll be talking about how to apply machine learning to problems!
- * mention the applied v. theoretical contrast.

Part 1) Applied Machine Learning case study: Drunk Driving Car Crashes

Part 2) [We totally change gears] SVM from scratch that exemplifies/applies the general math process that each ML project follows (by that I mean: Representation, Evaluation, Optimization)

The main goal here is to expose you to a wide spectrum of technical/theoretical machine learning considerations in as applied of a setting as possible.

Special Thanks

Dr. D

Dr. Michael Bloem

└ Special Thanks

Dr. D
Dr. Michael Bloem

I'd like to offer a very special thank you to Dr. Devereaux and Dr. Michael Bloem for all that they've done to help me in putting this together – would not be possible without them!

Machine Learning Overview

Steps in the Machine Learning Process

Step 0: Identify The Problem

Step 1: Get the Data

Step 2: Data Exploration

Step 3: Data Preparation

Step 4: Model Selection

Step 5: Cross-validation/Hyper-parameter tuning

Building a Support Vector Machine from Scratch

Representation

Evaluation

Optimization

Exploring Scikit-Learn and applying to GR Crash dataset

Machine Learning From Scratch

Machine Learning Overview

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- Evaluation
- Optimization

Exploring Scikit-Learn and applying to GIt Crash dataset

Pull a graph of google search trends indicating how terms like "Data Science" and "Machine Learning" have blown up.

Try to form talk around hitting on the theoretical mathematical side of ML as well as the difficulties/complexities faced in Applied ML

data + algorithms = predicting the future (it's really a lot more than this – understanding context and how to frame the question (usually) from a business perspective is huge)

classification v. regression

supervised/unsupervised/reinforcement learning

when talking on reinforcement learning, mention and recommend

AlphaGo documentary (it's on netflix!)

considerations/complexities in building ML models

What is Machine Learning?



Machine Learning

Arthur Samuel:

Machine learning is “Field of study that gives computers the ability to learn without being explicitly programmed”.

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Machine Learning From Scratch

└ Machine Learning Overview

└ What is Machine Learning?

What is Machine Learning?



Machine Learning

Arthur Samuel:

Machine learning is "Field of study that gives computers the ability to learn without being explicitly programmed".

Even according to the experts, the exact definition of the field of machine learning is a bit fuzzy, but As early as 1959, Arthur Samuel quote. .

also, include Ng's explanation from MLYearning!

What is Machine Learning

data + algorithms = predicting the future
combo of statistics, calculus, etc...

Machine Learning From Scratch

└ Machine Learning Overview

└ What is Machine Learning

What is Machine Learning

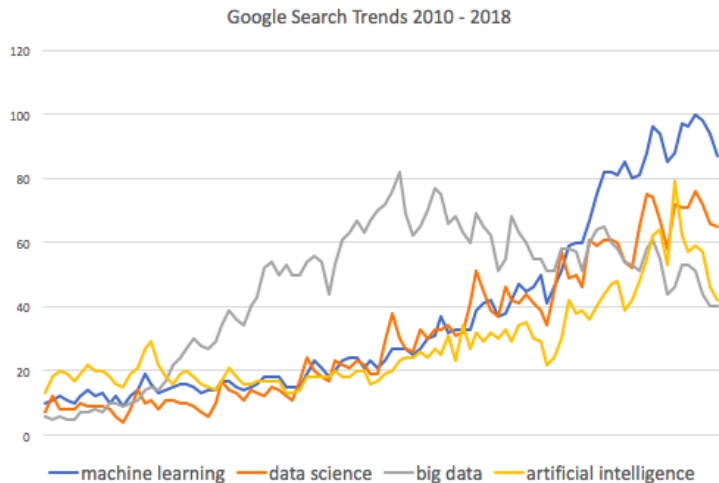
data + algorithms = predicting the future
combo of statistics, calculus, etc...

ML techniques can be applied to a wide range of problems in diverse industries. In fact, ML has become ubiquitous in our everyday lives *

Siri/ Amazon Alexa

- * Recommendation systems (amazon, netflix)
- * Fraud Detection
- * Disease diagnosis
- * Supply Chain Optimization

According to Google...



What has caused this spike?

1. Data Availability

- ▶ digital data
- ▶ lot (sensor data)

2. Computational Scale

- ▶ Moore's Law

Machine Learning From Scratch

└ Machine Learning Overview

└ What has caused this spike?

What has caused this spike?

1. Data Availability
 - digital data
 - lot (sensor data)
2. Computational Scale
 - Moore's Law

The math that powers machine learning algorithms has been around for quite a few years... so what's changed?

1. Data Availability (here we should just a few examples)
2. Computational Scale (NG MLY 01 pg 10)

The rise of the big data era has given us access to astounding amounts of data. That phenomenon paired with with the exponential growth we've experienced in computational advances, has created the perfect storm for the emergence of the field of machine learning.

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Building a Support Vector Machine from Scratch

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Machine Learning From Scratch

- └ Steps in the Machine Learning Process
 - └ Step 0: Identify The Problem



Step 0 is to identify a problem that can be framed in such a way that it can be solved using machine learning.

Let's say that you work for the city of Grand Rapids, and you find that there are an increased number of hit and runs when the driver 1 was drinkin.

Do some research, maybe find a way to graph this?? You can do it!

Get the Data

This may look like:

- ▶ SQL query
- ▶ CSV download
- ▶ Web-scraping
- ▶ Designing experiments/surveys and collecting data yourself

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- ▶ SQL query
- ▶ CSV download
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- ▶ Designing experiments/surveys and collecting data yourself

In our case, we'll head to [GRData](#).

Machine Learning From Scratch

└ Steps in the Machine Learning Process

└ Step 1: Get the Data

└ Get the Data

[Get the Data](#)

This may look like:

- SQL query
- CSV download
- Web-scraping
- Designing experiments/surveys and collecting data yourself

In our case, we'll head to [GRData](#).

Step 1! Obtaining the data you'll need looks very different depending on what domain you're working in. In some instances, it can be fairly simple and straightforward, for example, In a business context, most often it will require querying some sort of internal database. Could also be downloading a csv file. In other instances, it may require a bit more creativity – For particular social research, you may need to scrape the web. In some cases, you may even need to collect some data yourself! Here are two examples:

1. You're developing a new data product at your company and are collecting data to fuel it
2. You're in public health and are working to make healthcare accessible to all residents of the greater GR area. You may need to conduct your own research to identify what may be inhibiting people from reaching healthcare.

In our case, we're lucky enough to have access to a meticulously maintained public database on the city of GR: GRData. Scroll through,

Get the Data

In our case, we'll head to [GRData](#)

```
In [33]: crash = pd.read_csv('Data/CGR_Crash_Data.csv')
         crash.head()
```

```
Out[33]:
```

	X	Y	OBJECTID	ROADSOFTID	BIKE	CITY	CRASHDATE	CRASHSEVER	CRASHTYPE	WORKZNEACT	...
0	-85.639647	42.927216	6001	929923	No	Grand Rapids	2007-02-16	Property Damage Only	Side-Swipe Same	Uncoded & Errors	...
1	-85.639487	42.927213	6002	935745	No	Grand Rapids	2007-06-22	Property Damage Only	Side-Swipe Same	Uncoded & Errors	...
2	-85.639387	42.927212	6003	926813	No	Grand Rapids	2007-01-08	Property Damage Only	Head-on	Work on Shoulder / Median	...
3	-85.639288	42.927210	6004	943813	No	Grand Rapids	2007-11-12	Property Damage Only	Side-Swipe Same	Uncoded & Errors	...
4	-85.639288	42.927210	6005	943791	No	Grand Rapids	2007-11-09	Property Damage Only	Parking	Uncoded & Errors	...

5 rows × 77 columns

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Machine Learning From Scratch

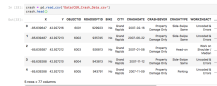
Steps in the Machine Learning Process

Step 1: Get the Data

Get the Data

[Get the Data](#)

In our case, we'll head to [GRData](#)



The screenshot shows a Jupyter Notebook interface. At the top, there's a code cell with the command `!curl -L https://raw.githubusercontent.com/GRData/GRData/master/basketball.csv`. Below it, a text cell says "In our case, we'll head to [GRData](#)". Then, another code cell displays the first few rows of a DataFrame. The DataFrame has columns: 'DATE', 'HOME_TEAM', 'AWAY_TEAM', 'HOME_SCORE', 'AWAY_SCORE', 'HOME_TEAM_POINTS', 'AWAY_TEAM_POINTS', 'HOME_TEAM_POINTS_PER_GAME', 'AWAY_TEAM_POINTS_PER_GAME', 'HOME_TEAM_POINTS_PER_GAME_POINTS', 'AWAY_TEAM_POINTS_PER_GAME_POINTS'. The first row shows a game between the Boston Celtics and the New York Knicks on 10/26/17, with the Celtics winning 101-95.

	DATE	HOME_TEAM	AWAY_TEAM	HOME_SCORE	AWAY_SCORE	HOME_TEAM_POINTS	AWAY_TEAM_POINTS	HOME_TEAM_POINTS_PER_GAME	AWAY_TEAM_POINTS_PER_GAME	HOME_TEAM_POINTS_PER_GAME_POINTS	AWAY_TEAM_POINTS_PER_GAME_POINTS
0	10/26/17	Boston Celtics	New York Knicks	101	95	101	95	101	95	101	95
1	10/27/17	Boston Celtics	New York Knicks	101	95	101	95	101	95	101	95
2	10/28/17	Boston Celtics	New York Knicks	101	95	101	95	101	95	101	95
3	10/29/17	Boston Celtics	New York Knicks	101	95	101	95	101	95	101	95
4	10/30/17	Boston Celtics	New York Knicks	101	95	101	95	101	95	101	95

After downloading the csv file, we can read the file into a pandas dataframe and explore it in our Jupyter notebook.

* note something about how we'll often refer to each row as an observation and each column as a feature

Explore the Data

- ▶ Verify data
- ▶ Visualize data
- ▶ Identify patterns
- ▶ Give direction to analysis

Machine Learning From Scratch

└ Steps in the Machine Learning Process

└ Step 2: Data Exploration

└ Explore the Data

Explore the Data

- Verify data
- Visualize data
- Identify patterns
- Give direction to analysis

Step 2! This is kind of an unstructured approach to understanding initial patterns in the data and potentially points of interest. This process isn't meant to reveal every bit of information a dataset holds, but rather give you direction in your analysis and potentially give you clues in how to process/model the data.[1] Now, if you're just emailed a csv file, this step is especially crucial, and it may take you some time to explore the data, get a feeling for what you're dealing with. If you are analyzing data that you work with day in and day out, this "exploration" process may be a bit more implicit.

The main idea here is to build an understanding of your data. Without an appreciation for the context of the data, it's just numbers. But when you see the data in context, it's fascinating, it's a story.

More often than not, your exploration of the data leads to more questions than answers.

Machine Learning From Scratch

└ Steps in the Machine Learning Process

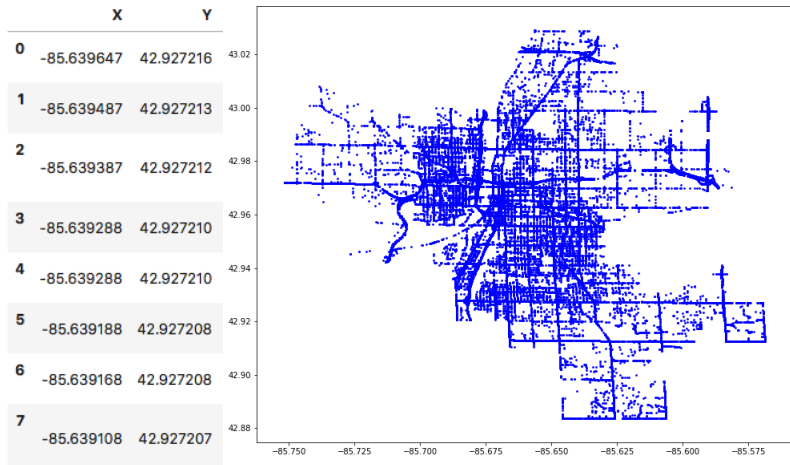
└ Step 2: Data Exploration

	X	Y
0	-85.639647	42.927216
1	-85.639487	42.927213
2	-85.639387	42.927212
3	-85.639288	42.927210
4	-85.639288	42.927210
5	-85.639188	42.927208
6	-85.639168	42.927208
7	-85.639108	42.927207

Machine Learning From Scratch

└ Steps in the Machine Learning Process

└ Step 2: Data Exploration

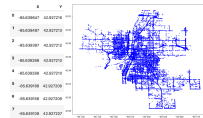


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Machine Learning From Scratch

└ Steps in the Machine Learning Process

└ Step 2: Data Exploration

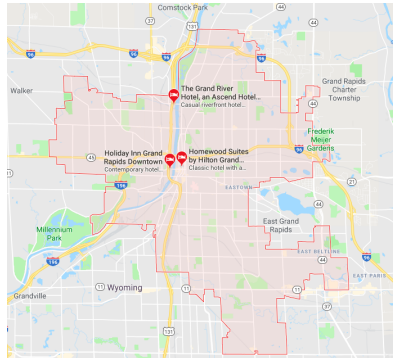
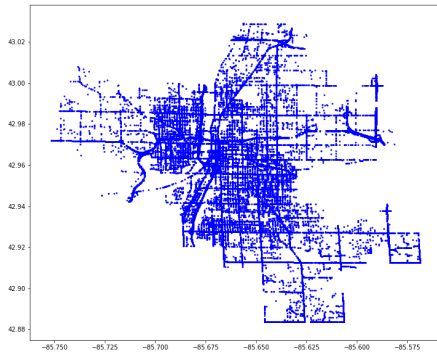


With our dataset, on car crashes, a logical place to begin would be the first two columns, containing latitudes and longitudes of each crash. This is just a snapshot of the data on the left side, and on the right, each dot represents a car crash.

Machine Learning From Scratch

└ Steps in the Machine Learning Process

└ Step 2: Data Exploration



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Machine Learning From Scratch

└ Steps in the Machine Learning Process

└ Step 2: Data Exploration

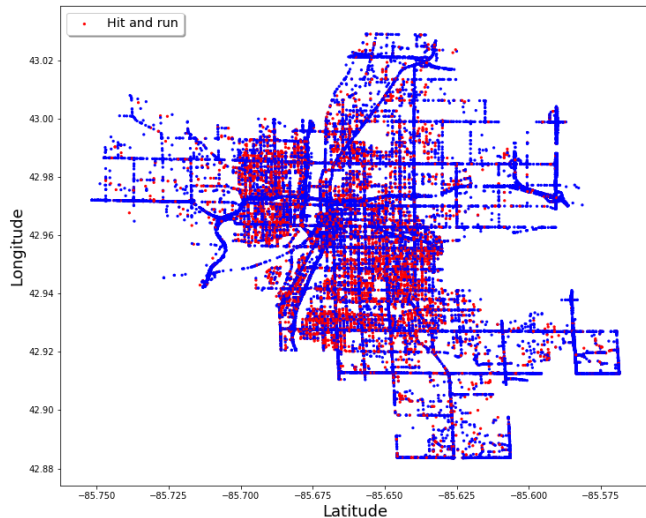


Now, this is pretty telling about our data, remember, there is nearly 73,000 crashes recorded, and if we juxtapose this plot with the city of GR, we actually see that the plot of crashes outline the city boundaries!

Machine Learning From Scratch

└ Steps in the Machine Learning Process

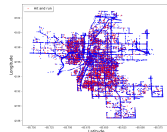
└ Step 2: Data Exploration



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Machine Learning From Scratch

- └ Steps in the Machine Learning Process
 - └ Step 2: Data Exploration



We may be interested in hit and runs...

I should add a caption or title to this plot

Check the variable's distribution

```
In [34]: crash = pd.read_csv('Data/CGR_Crash_Data.csv')
         crash.head(3)
```

```
Out[34]:
```

	X	Y	OBJECTID	ROADSOFTID	BIKE	CITY	CRASHDATE	CRASHSEVER	CRASHTYPE	WORKZNEACT	...
0	-85.639647	42.927216	6001	929923	No	Grand Rapids	2007-02-16	Property Damage Only	Side-Swipe Same	Uncoded & Errors	...
1	-85.639487	42.927213	6002	935745	No	Grand Rapids	2007-06-22	Property Damage Only	Side-Swipe Same	Uncoded & Errors	...
2	-85.639387	42.927212	6003	926813	No	Grand Rapids	2007-01-08	Property Damage Only	Head-on	Work on Shoulder / Median	...

3 rows x 77 columns

```
In [32]: crash.VEH3TYPE.value_counts()
```

```
Out[32]:
```

Uncoded & Errors	67212
Passenger Car, SUV, Van	4788
Pickup Truck	503
Motorhome	327
Truck Under 10,000 lbs	63
Truck / Bus (Commercial)	62
Other Non-Commercial	10
Motorcycle	10
Go-cart / Golf Cart	2

Name: VEH3TYPE, dtype: int64

Steps in the Machine Learning Process

-Step 2: Data Exploration

- Check the variable's distribution

Check the variable's distribution

[illegible]

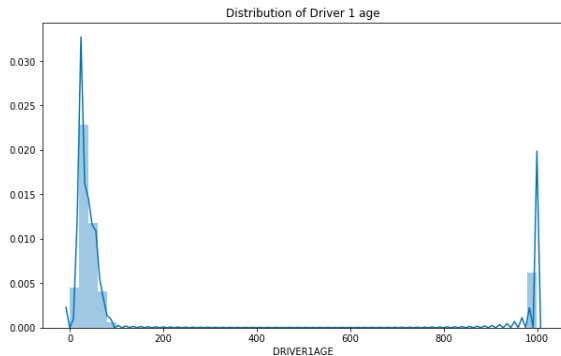
It's also often very helpful to check the distribution of the different variables. For example, our dataset contains many characteristics about what it defines as "DRIVER1", "DRIVER2", "DRIVER3". When I first came across that, I was impressed, like that's some seriously accurate data! But upon further examination, we find that many of the "DRIVER2" and "DRIVER3" columns are empty or contain errors. (This makes sense... not all crashes involve 3 driver!)

When we check the counts of the different values found in the "VEH3" column, we see that over 67,000 of them are errors! Now, this doesn't mean that the column is useless, but in terms of building a predictive model, this column probably won't be much help, so as we'll see in the data processing step, we'll end up dropping it.

Check the variable's distribution

```
In [41]: fig, ax = plt.subplots(figsize=(10,6))  
         ax.set_title('Distribution of Driver 1 age')  
         sns.distplot(crash.DRIVER1AGE)
```

```
Out[41]: <matplotlib.axes._subplots.AxesSubplot at 0x1a1a742080>
```



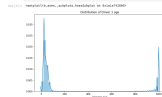
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Machine Learning From Scratch

- └ Steps in the Machine Learning Process
 - └ Step 2: Data Exploration
 - └ Check the variable's distribution

Check the variable's distribution

```
In [101]: fig, ax = plt.subplots(figsize=(10, 5))  
         ax.hist(hypothesis_distribution_of_driver_age)
```

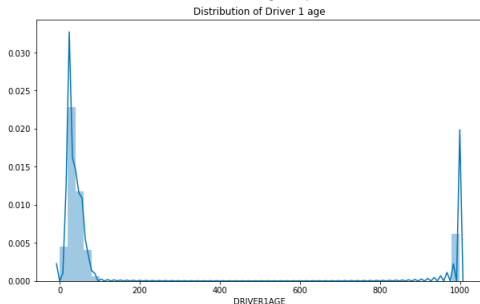


Continuing on, here we check the distribution of the age's of all the "DRIVER1"s recorded in the dataset. In my head, I would think that age would be an important feature in car crashes. And so we check it out, and it appears that there are a ton of instances bunched up between 1 and 100... that makes sense... then there is also a decent cluster of observations around 1000 years old... that does not make sense.

Check the variable's distribution

```
In [45]: fig, ax = plt.subplots(figsize=(10,6))  
         ax.set_title('Distribution of Driver 1 age')  
         sns.distplot(crash.DRIVER1AGE)
```

There are 8979 Driver 1's recorded as being 999 years-old.



```
In [46]: print('There are', crash.DRIVER1AGE[crash.DRIVER1AGE == 999].count(), "driver 1's recorded as being 999 years-old.")
```

There are 8979 driver 1's recorded as being 999 years-old.

Machine Learning From Scratch

- └ Steps in the Machine Learning Process
 - └ Step 2: Data Exploration
 - └ Check the variable's distribution

Check the variable's distribution



Nearly 9,000 driver 1's are recorded as being 999 years-old.. That is a good thing to know before trying to build a predictive model, as it seriously skews the data. We'll address that in our data processing stage.

Next, we move onto data preparation. This is the stage where we make the final manipulations to our data before feeding it into our ML algorithm. Now, you could make an argument that preparing the data is the most important part of the machine learning workflow. After all it's the data that fuels the algorithm, garbage in, garbage out! It's been shown time and time again that more/bigger data beats a better algorithm everytime. Though it usually appears to be straightforward, this step can often require a lot of creativity.

Data Selection

Use as minimal features as possible

1. Computationally efficient
2. Easier to interpret
3. Simpler is better

Data Selection

Use as minimal features as possible

1. Computationally efficient
2. Easier to interpret
3. Simpler is better

```
In [8]: crash = pd.read_csv('Data/CGR_Crash_Data.csv')
crash = crash[['X', 'Y', 'CRASHSEVER', 'DRIVER1AGE', 'DRIVER1SEX',
               'EMRGVEH', 'HITANDRUN', 'SPEEDLIMIT', 'HOUR', 'MOTORCYCLE',
               'NUMOFINJ', 'D1COND', 'D1DRINKIN']]
crash.columns

Out[8]: Index(['X', 'Y', 'CRASHSEVER', 'DRIVER1AGE', 'DRIVER1SEX', 'EMRGVEH',
               'HITANDRUN', 'SPEEDLIMIT', 'HOUR', 'MOTORCYCLE', 'NUMOFINJ', 'D1COND',
               'D1DRINKIN'],
              dtype='object')
```

Machine Learning From Scratch

Steps in the Machine Learning Process

Step 3: Data Preparation

└ Data Selection

Data Selection

Use as minimal features as possible

1. Computationally efficient
2. Easier to interpret
3. Simpler is better

Feature Engineering



'Coming up with features is difficult, time-consuming, requires expert knowledge. Applied machine learning is basically feature engineering.'

Prof. Andrew Ng



'At the end of the day, some machine learning projects succeed and some fail. What makes the difference? Easily the most important factor is the features used.'

Prof. Pedro Domingos

Machine Learning From Scratch

└ Steps in the Machine Learning Process

└ Step 3: Data Preparation

└ Feature Engineering

Feature Engineering



"Coming up with features is difficult, time-consuming, requires expert knowledge. Applied machine learning is basically feature engineering."
Prof. Andrew Ng



"At the end of the day, some machine learning projects succeed and some fail. What makes the difference? Easily the most important factor is the features used."
Prof. Pedro Domingos

So now we have our 13 features that we've chosen to use, and we could just send these raw features into our algorithm, and it may perform well, but it may not. It's important to remember that our ultimate goal is to build a predictive model that can make accurate predictions on new/unseen observations. When all the data comes in from a car crash that just happened, we want to be able to accurately predict whether or not it was a drunk driver that caused it.

Feature engineering is the process of transforming raw data into features that better represent the underlying problem to the predictive models, resulting in improved model accuracy on unseen data. - Jason Brownlee [2]

We acknowledge, however, that the data that's being recorded (from those UD10 reports) isn't necessarily guaranteed to accurately represent reality. Which is an important thing if we want to build accurate, stable predictive models.

The examples that we show here are absolutely not exhaustive when it

Feature Engineering: *transforming "hour" variable*

$$\begin{bmatrix} 12 \\ 2 \\ 4 \\ 18 \\ 19 \\ 6 \\ \vdots \end{bmatrix}$$

Feature Engineering: *transforming "hour" variable*

$$\begin{bmatrix} 12 \\ 2 \\ 4 \\ 18 \\ 19 \\ 6 \\ \vdots \end{bmatrix} \implies f(x) = \frac{2 \cdot \pi \cdot (\text{hour})}{24}$$

Feature Engineering: *transforming "hour" variable*

$$\begin{bmatrix} 12 \\ 2 \\ 4 \\ 18 \\ 19 \\ 6 \\ \vdots \end{bmatrix} \Rightarrow f(x) = \frac{2 \cdot \pi \cdot (\text{hour})}{24} \Rightarrow \begin{bmatrix} 3.14 \\ 0.52 \\ 1.03 \\ 4.71 \\ 4.98 \\ 1.57 \\ \vdots \end{bmatrix}$$

Machine Learning From Scratch

└ Steps in the Machine Learning Process

└ Step 3: Data Preparation

└ Feature Engineering: *transforming "hour" variable*Feature Engineering: *transforming "hour" variable*

$$\begin{bmatrix} 12 \\ 2 \\ 4 \\ 18 \\ 19 \\ 6 \\ \vdots \end{bmatrix} \implies f(x) = \frac{x - 0(\text{hour})}{24} \implies \begin{bmatrix} 3.14 \\ 0.52 \\ 1.03 \\ 4.71 \\ 4.98 \\ 1.57 \\ \vdots \end{bmatrix}$$

It contains at what hour the crash occurred at (ranging from 0-23). It did not make sense to me to treat this column as a numerical variable, since the model would interpret 2pm as twice 1pm... while that does not make logical sense. However, I felt that to treat each hour as its own category wouldn't accurately capture the information that the hour conveys (for example, it would not capture the fact that 12pm and 12am are 12 hours apart, while 12pm and 1pm are next to each other), so I set out to transform this feature in order to convey more meaning to our algorithm. Here's what I did.

Feature Engineering: *transforming "hour" variable*

$$\begin{bmatrix} 3.14 \\ 0.52 \\ 1.03 \\ 4.71 \\ 4.98 \\ 1.57 \\ \vdots \end{bmatrix} \Rightarrow \underbrace{\begin{bmatrix} 0.00 \\ 0.47 \\ 0.86 \\ -0.99 \\ -0.97 \\ 1.0 \\ \vdots \end{bmatrix}}_{\sin(f(x))}, \underbrace{\begin{bmatrix} -1.0 \\ 0.87 \\ 0.51 \\ -0.002 \\ -0.26 \\ 0.001 \\ \vdots \end{bmatrix}}_{\cos(f(x))}$$

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Machine Learning From Scratch

Steps in the Machine Learning Process

Step 3: Data Preparation

Feature Engineering: *transforming "hour" variable*

Feature Engineering: *transforming "hour" variable*

$$\begin{bmatrix} 3.14 \\ 0.52 \\ 1.03 \\ 4.71 \\ 4.98 \\ 1.57 \\ \vdots \end{bmatrix} \implies \begin{bmatrix} 0.00 \\ 0.47 \\ 0.86 \\ -0.99 \\ -0.97 \\ 1.0 \\ \vdots \end{bmatrix}, \begin{bmatrix} -1.0 \\ 0.87 \\ 0.51 \\ -0.002 \\ -0.26 \\ 0.001 \\ \vdots \end{bmatrix}$$

$\sin(\pi(x))$ $\cos(\pi(x))$

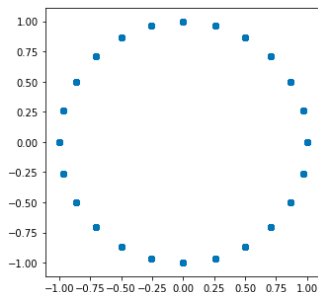
Okay, so we have this new vector.. it doesn't look too helpful at the moment. But now we map that vector to two other vectors

Feature Engineering: *transforming "hour" variable*

```
In [193]: crash['HOUR_X']=np.sin(2. * np.pi * crash.HOUR / 24.)  
          crash['HOUR_Y']=np.cos(2. * np.pi * crash.HOUR / 24.)
```

```
In [194]: # Hence, the time of day is now cyclic (just as in reality)  
          plt.figure(figsize = (5,5))  
          plt.scatter(crash.HOUR_X, crash.HOUR_Y)
```

```
Out[194]: <matplotlib.collections.PathCollection at 0x1a0daeca20>
```



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Machine Learning From Scratch

Steps in the Machine Learning Process

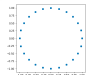
Step 3: Data Preparation

Feature Engineering: *transforming "hour" variable*

Feature Engineering: *transforming "hour" variable*

```
In [109]: import pandas as pd
import numpy as np
import matplotlib.pyplot as plt

In [109]: # Create the time of day for new entries based on the meeting
plt.figure(figsize=(10,10))
plt.scatter(hour,day)
```

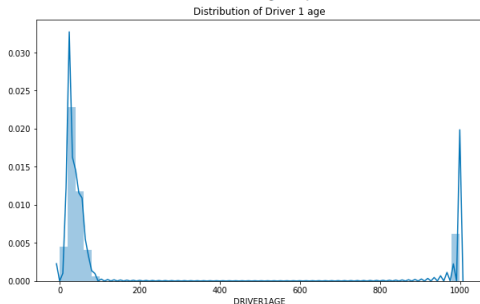


transferring that all into code...

Feature Engineering: *imputing missing ages*

```
In [45]: fig, ax = plt.subplots(figsize=(10,6))  
ax.set_title('Distribution of Driver 1 age')  
sns.distplot(crash.DRIVER1AGE)
```

There are 8979 Driver 1's recorded as being 999 years-old.



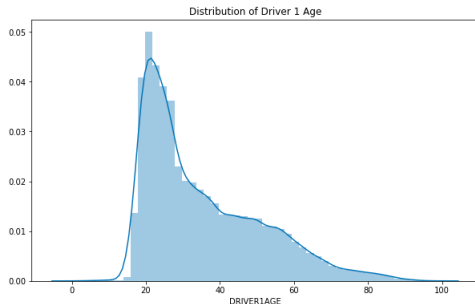
```
In [46]: print('There are', crash.DRIVER1AGE[crash.DRIVER1AGE == 999].count(), "driver 1's recorded as being 999 years-old.")
```

There are 8979 driver 1's recorded as being 999 years-old.

Feature Engineering: *imputing missing ages*

```
In [90]: # This age distribution looks much better!  
fig, ax = plt.subplots(figsize=(10,6))  
ax.set_title('Distribution of Driver 1 Age')  
sns.distplot(crash['DRIVER1AGE'])
```

```
Out[90]: <matplotlib.axes._subplots.AxesSubplot at 0x1a21b50240>
```



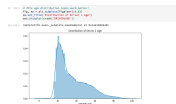
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Step 3: Data Preparation

Feature Engineering: *imputing missing ages*

Feature Engineering: *imputing missing ages*



Now, earlier when we were exploring our data and checking the distribution of the ages, we found that there are about 9,000 erroneous ages.

When you have erroneous/outright missing data you have a couple different options.

1. drop them entirely
2. impute mean/median (make this choice depending on distribution of data)

For most cases, one of those two options will work just fine. In our case, with nearly 9,000 errors, I'm not sure any of those would make sense, so we'll opt for a bit more involved technique. (The technical term is "Multiple Imputation by Chained Equations", affectionately known as MICE). What this means is that we will fit a linear regression model to our data to predict what the missing ages could be. We can think of these as making an educated guess.

Data Processing

Two general types of data to deal with:

- ▶ Numerical variables (Quantitative)
 - ▶ Driver 1 age, number of injuries, etc
- ▶ Categorical variables (Qualitative)
 - ▶ Hit and run, motorcycle involved, etc

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Data Processing

Two general types of data to deal with:

- Numerical variables (Quantitative)
 - Driver 1 age, number of injuries, etc
- Categorical variables (Qualitative)
 - Hit and run, motorcycle involved, etc

Now, we move onto processing the data that we've selected. The data processing stage naturally diverges into two substeps: dealing with numerical variables, and dealing with categorical variables.

It's important to note that some of the preprocessing steps we'll talk about here may actually be necessary for you to do to get the data in a format where you can explore it.

Numerical variables are quantitative – it's something you can measure. In our case, some numerical variables are Driver1 age, and number of injuries.

Categorical variables are qualitative, in our case, we have some binary categorical variables: like whether or not the crash was a hit and run, whether or not a motorcycle was involved. It's either one or the other. Variables can of course have multiple categories, for example, which car insurance provider you choose: (Nationwide, Statefarm, BlueCross BlueShield) There is obviously a lot of them, but all drivers fit into one of those categories... or at least they should.

There is some grey area between the two – maybe mention speedlimits or

Data Processing: *numerical variables*

```
In [91]: crash[['X', 'Y', 'DRIVER1AGE', 'NUMOFINJ']].head()
```

```
Out[91]:
```

	X	Y	DRIVER1AGE	NUMOFINJ
0	-85.639647	42.927216	62.0	0
1	-85.639487	42.927213	31.0	0
2	-85.639387	42.927212	22.0	0
3	-85.639288	42.927210	30.0	0
4	-85.639288	42.927210	44.0	0

Data Processing: *numerical variables*

```
In [34]: sc_X = StandardScaler()
X_scaled = sc_X.fit_transform(crash[['X', 'Y', 'DRIVER1AGE', 'NUMOFINJ']])
X_scaled_df = pd.DataFrame(X_scaled, columns = ['X', 'Y', 'DRIVER1AGE', 'NUMOFINJ'])
crash_ = crash.drop(['X', 'Y', 'DRIVER1AGE', 'NUMOFINJ'], axis=1)
crash = pd.concat([X_scaled_df, crash_], axis=1)
crash.iloc[:, :4].head()
```

```
Out[34]:
```

	X	Y	DRIVER1AGE	NUMOFINJ
0	0.406318	-0.996140	1.685157	-0.416816
1	0.411006	-0.996237	-0.269018	-0.416816
2	0.413936	-0.996298	-0.836360	-0.416816
3	0.416866	-0.996358	-0.332056	-0.416816
4	0.416866	-0.996358	0.550474	-0.416816

Data Processing: *categorical variables*

```
In [111]: crash[['CRASHSEVER', 'DRIVER1SEX', 'EMRGVEH', 'HITANDRUN',  
                'MOTORCYCLE', 'D1COND', 'D1DRINKIN']].head()
```

```
Out[111]:
```

	CRASHSEVER	DRIVER1SEX	EMRGVEH	HITANDRUN	MOTORCYCLE	D1COND	D1DRINKIN
0	Property Damage Only	F	No	Yes	No	Appeared Normal	No
1	Property Damage Only	M	No	Yes	No	Unknown	No
2	Property Damage Only	F	No	No	No	Appeared Normal	No
3	Property Damage Only	M	No	Yes	No	Appeared Normal	No
4	Property Damage Only	M	No	No	No	Appeared Normal	No

Data Processing: *categorical variables*

In [135]: `dummies.head()`

Out[135]:

	CRASHSEVER_Fatal	CRASHSEVER_Injury	CRASHSEVER_Property Damage Only	DRIVER1SEX_F	DRIVER1SEX_M	DRIVER1SEX_U
0	0	0	1	1	0	0
1	0	0	1	0	1	0
2	0	0	1	1	0	0
3	0	0	1	0	1	0
4	0	0	1	0	1	0

5 rows × 21 columns

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└ Data Processing: *categorical variables*

Data Processing: *categorical variables*

	gender	sex	year	make	model	type	trans	driv	flr	hwy	city	mpg	displ	wt	qtr	htr	htr2	htr3	htr4	htr5	htr6	htr7	htr8	htr9	htr10	htr11	htr12	htr13	htr14	htr15	htr16	htr17	htr18	htr19	htr20	htr21		
0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

8 rows x 21 columns

Here we have our categorical variables. In our excel spreadsheet, this looks great, nice and clean.., but if we want to squeeze this data into a model, we need to manipulate it into a format that makes sense for math. Basically, we are going to turn all of our categories into 1's and 0's, representing yes' and no's. You can think of this as transforming the data to turn everything into a yes or no question.

Was the driver sex male? No. Was the driver sex female? yes.

I've seen this called creating dummy variables, or one-hot-encoding

This is just a snapshot, you see that our columns of categorical variables grew from 7 to 21

Come up with more concrete explanation

Choosing a Model/Representation

	Classification	Regression
Supervised	<ul style="list-style-type: none">• Logistic Regression• Naive-Bayes• KNN• SVM	<ul style="list-style-type: none">• Linear Regression• Decision Trees• Random Forests
Unsupervised	<ul style="list-style-type: none">• Apriori• Hidden Markov Model	<ul style="list-style-type: none">• PCA• K-means• SVD

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Choosing a Model/Representation

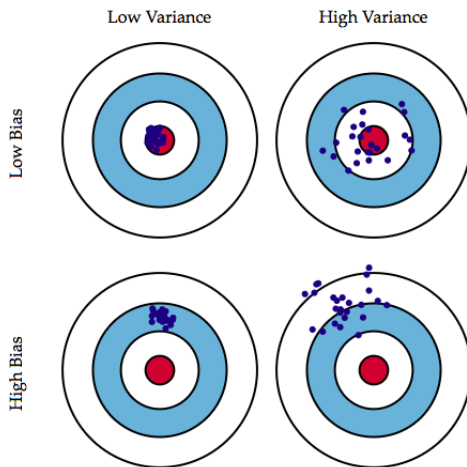
	Classification	Regression
Supervised	<ul style="list-style-type: none">• Logistic Regression• Naïve-Bayes• KNN• SVM	<ul style="list-style-type: none">• Linear Regression• Decision Trees• Random Forests
Unsupervised	<ul style="list-style-type: none">• Apriori• Hidden Markov Model	<ul style="list-style-type: none">• PCA• K-means• SVD

And with that, our data is ready to be fed into a predictive model! The final step is to choose which predictive model to use. There are hundreds to choose from, and trade-offs associated with each. The good news is, as we alluded to earlier there are different types of machine learning problems and each come with their own set of algorithms – so this narrows down our search considerably.

In our case, we're working on a supervised classification problem, so the upper left hand corner displays some common algorithms for problems like ours. It's very common to test a handful of them and choose the one that performs best on your dataset (or even combine some of them into an ensemble model.)

Remember, the ultimate objective to choose a model that learns a predictive rule (which comes in the form of an equation) that can be generalized to new observations (both for classification and regression)

Bias-Variance Tradeoff



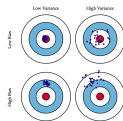
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Bias-Variance Tradeoff

Bias-Variance Tradeoff



One critical aspect to take into consideration when choosing a model is called the bias-variance tradeoff

So first, I'm going to define what I mean when I talk about the terms "bias" and "variance" in the context of machine learning, then we are going to look at some simplified examples (using this dataset here) in the regression context that I think really well convey the essence of applied machine learning:

Maybe still show my graphs?

mention statistical techniques necessary to combat variance, like bagging

maybe mention regularization?

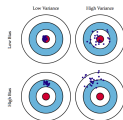
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Bias-Variance Tradeoff



Throughout this section, add notes for each of the headers in the jupyter notebook!

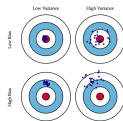
Also, do not forget to look over Lin alg for SVM notebook!efz

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└ Bias-Variance Tradeoff

Bias-Variance Tradeoff



Here we'll first be going through a general example of building an svm from scratch on a toy dataset, then apply some of Python's ml tools to our crash data set to predict whether or not a car crash was caused by a drunk driver!

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Here, we will begin by importing the necessary libraries – (audience should just run these). So here is what our plotted data looks like. And here is a snapshot of data set. Note that for each data point (each row/each dot), we have an x_1 value, and X_2 value, and a y value (which represents the target variable, which we are trying to predict). In this case, we've rather defined the red data points to be labeled as -1 and the blue data points to be labeled as 1. It may seem weird to call them x_1 and x_2 , but we'll address why we do that in a little bit.

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Representation: Support Vector Machine

The first step in building any sort of predictive model is choosing a representation. For our example today, we choose a Support Vector Machine. Big picture - The goal of a SVM is to To find the optimal separating hyperplane which maximizes the margin of the training data. Now, a hyperplane is kind of like a fancy word for a line, or maybe better put, it's a general way to talk about a line. The black line on this graph of our dataset is a hyperplane that separate the two classes (red/blue). Since our data is two dimensional (we have an x , and a y (1, 2)) the hyperplane is a line

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How do we find the optimal separating hyperplane?:

Now, as we mentioned, the goal of the hyperplane is to find the optimal separating hyperplane, so how do we do that? It appears that there can be many different separating hyperplanes (often there is infinite). We're going to choose the hyperplane that is as far away as possible from each class of datapoints.

We want to maximize the margin because It generalizes better to classifying unseen observations - \hat{y} (meaning that it makes better predictions)

If we have our usual equation for a line: $y=mx+b$, then all we need to do is find that optimal m and b that characterize the optimal hyperplane!

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Understanding the Definition of a hyperplane:

As we've seen previously, the separating hyperplane that we keep referring to (in 2-d) is just a line. I'm confident that you're familiar with the way we define lines:

Now, a quick refresher that b is just a constant that represents the y-intercept, m (usually defines the slope) is a coefficient to the variable x (also a constant) and the variable y even has a coefficient as well, in this case it's 1. if we try to expand this equation $y=mx+b$ to more and more dimensions(variables), it's not a real great form to express it in. So instead, we choose to set the whole equation equal to zero. With some algebraic manipulation, we get that:

So, that looks a bit unnatural..so its common convention to represent all coefficients/constants with β , and all variables with X_i , so that we don't run out of variables to use.

In our Crash data, we use 14 variables...

maybe change the betas to w 's?

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Quick refresher on the dot product:

Now, we're going to talk for a minute about the dot product. The dot product has many different names across fields of mathematics: inner product, and linear combination are also common. Regardless of its name, it is a useful operation to use between vectors. To put it simply, if you take the dot product of two vectors, you multiply all their corresponding elements and take the sum. (note that the vectors must have the same dimensions).

The output of the dot product is not another vector, but just a scalar value.

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Dot product as distance from hyperplane:

Now you'll notice that this dot product indeed looks very similar to the way that we've defined the equation of a hyperplane. It turns out that, when we take the dot product of our weights vector \vec{w} and a single datapoint $\vec{x}^{(i)}$, the resulting number that we get can be thought of as the distance from the data point to the hyperplane (how far away it is). And since we're trying to maximize the width of our margin, having an efficient way to calculate how far away each datapoint is from the hyperplane proves to be crucial.

Now, if we're being mathematically rigorous, we may want to frame that a bit differently, but at least for all intensive purposes, we can think of it this way!

The fact that we've defined the equation of a hyperplane to be the dot product of our weights and features equal to zero implies that the hyperplane and the weights vectors are perpendicular (aka orthogonal).

And since they are orthogonal, we're able to exploit some linear algebra

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The Hinge Loss Function is defined as:

Now, armed with this ability to calculate how far away each data point is from the hyperplane, we can now use the Hinge Loss Function to quantify how wrong each of our predictions are!

One more important thing to note about the dot product is that it is signed, meaning that it can be either positive or negative, namely, data points below the hyperplane will have a negative distance from the hyperplane, and datapoints above the hyperplane, will have a positive distance from hyperplane.

Talk about how we will predict which class each data point comes from, then use the hinge loss to tell us how wrong we are.

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The Hinge Loss Function is defined as (Part 2): Breaking it down
1 minus y times the dot product of the weights vector and the datapoint itself.

Let's break this down piece by piece. First, we'll look at the inputs. \vec{w} is a vector of weights (coefficients) in the linear equation. $\vec{x}^{(i)}$ is a vector representing a single datapoint (the i^{th} datapoint), or a single row in our dataset. $y^{(i)}$ is the label associated with the datapoint (which is either 1 or -1). The output is a scalar value (a number) representing a penalty for how wrong our prediction was. The greater the penalty, the worse our estimated weights were in classifying the data.

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The Hinge Loss Function is defined as (Part 3): little subscript plus sign

One thing I've neglected to mention thus far is the little subscript plus sign at the end of the loss function. That little plus sign denotes that our loss function only looks at positive values, meaning that the output of function is a negative value, it's just going to change it to zero. This intuitively makes sense! If we get a negative penalty for our algorithm... that means that the prediction must be very correct, so instead, we'll just assign a penalty of 0, basically no penalty at all.

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The Hinge Loss Function is defined as (Part 4): working it out

Now, if you actually try to work this out with the datapoints, it can be a bit confusing, as there are lots of negatives and the sign of the function is constantly changing, so I've included this little table that works out small examples for all 4 cases, when the data point is correctly and incorrectly classified from the negative class, and when the data point was correctly and incorrectly classified from the positive class. For these little examples, I've assumed that the datapoint is 3 units away from the hyperplane. You'll notice if you skip to the bottom that the penalty for both incorrectly classified datapoints is 4, while the penalty for the correctly classified datapoints is 0.

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The Hinge Loss Function is defined as (Part 5): essence of ml

This is really worth emphasizing, because it doesn't just apply to SVM's but is the basis of machine learning. Machines learn by associating a quantitative penalty to incorrect predictions. The machine then sets out to minimize the penalty, which ultimately will result in making the maximum amount of correct predictions.

This is the essence of the current state of artificial intelligence. All AI is based on this principle, everything from autonomous vehicles, to amazon's recommendation system.

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Hinge Loss with regularization term:

Now, with the hinge loss function we've defined, when we try to minimize the loss function, we will (if possible) find a separating hyperplane that perfectly classifies the data i.e. no misclassifications. Which sounds great! The only problem with that is that there are any outliers in our dataset, it can seriously skew the hyperplane. Below we have two nearly identical datasets...the one on the right has one outlier (circle it with mouse) and it has completely changed our hyperplane.

Again, we need to remember that our goal is to find a hyperplane that will best classify new datapoints...so we don't want it to be affected by outliers.

The λ coefficient acts as a tuning parameter (in our example, we will explicitly hard-code a value for lambda), but generally, as the value for lambda gets smaller and smaller (approaches 0), the margin grows wider (to the point of misclassifying data points). As the value for lambda gets larger and larger, the margin will get smaller and smaller (to the point of

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Now, we've been talking quite a bit about minimizing the penalty to our algorithm for mis-classifying data points, but it is not immediately obvious how to minimize the penalty...

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Optimization

Exploring Scikit-Learn and applying to GIt Crash dataset

To do next:

Watch Andrew Ng's explanation of stochastic gradient descent and take notes in order to explain!

Then also outline exactly how to calculate the gradient of the hinge loss function for misclassified and correctly classified datapoints, then explicitly show the update rules.

Machine Learning Overview

Steps in the Machine Learning Process

Step 0: Identify The Problem

Step 1: Get the Data

Step 2: Data Exploration

Step 3: Data Preparation

Step 4: Model Selection

Step 5: Cross-validation/Hyper-parameter tuning

Building a Support Vector Machine from Scratch

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<https://www.sisense.com/glossary/data-exploration/>



<https://towardsdatascience.com/understanding-feature-engineering-part-2-categorical-data-f54324193e63>



<http://scott.fortmann-roe.com/docs/BiasVariance.html>