Understanding what causes recent mass layoffs on a globe

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Abstract: We downloaded the mass layoffs dataset from Kaggle.com. The mass layoffs was tracked in terms of time, country origin, industry type, company name, company stage, and fund raised after the mass laidoff event. This dataset would provide an insight to a global mass layoff phenomenon.

The details of the dataset as followed:

Company: Name of the company

Location: Location of the company layoff

Industry: Type of Industry of the company

Total_Laid_Off: Number of employees laid off

Percentage_Laid_Off: Percentage of employees laid off

Date: Date of layoff

Stage: Stage of Funding

Country: Country of the company

Funds_Raised: Fund raised by the company in Millions USD $

What we will explore in this jupyter notebook:

We will:

- Clean the mass layoff data.
- Present a Exploratory Data Analysis (EDA) for mass layoff that ranges from 2020 Jan to 2023 April.

What we will have three tasks:

We will:

- in Task 1: Test model 1: time series of mass layoff.
- in Task 2: Test model 2: linear regression model.
- in Task 3: Test model 3: decision tree model.

What we will pursue in the future:

We plan to:

- Consider more variables in our linear regression model.
- Collect stock market and country GDP data.
- Build a user-friendly plateform for predicting a mass layoff.

```
In [148…  import pandas as pd
          import numpy as np
          import matplotlib.pyplot as plt
          import matplotlib.dates as dates
          import seaborn as sns
          import plotly.express as px

          print(pd.__version__)

          1.5.3
```

Load mass layoff data

```
In [149…  data = pd.read_csv("layoffs.csv")
```

```
In [150…  data.shape

Out[150]:  (2545, 9)
```

```
In [151…  type(data)

Out[151]:  pandas.core.frame.DataFrame
```

Note: we believe that funds raised is defined as a profit or funding raising of a company after a layoff event

We can actually pin down the list of employees at the mass layoff event: np.where((data['date']=='2022-11-09') & (data['company']=='Meta'))

```
In [152…  data.describe()
```

Out[152]:

	total_laid_off	percentage_laid_off	funds_raised
count	1746.000000	1694.000000	2297.000000
mean	256.022337	0.260577	814.143794
std	841.557354	0.258415	5448.104463
min	3.000000	0.000000	0.000000
25%	38.000000	0.100000	50.000000
50%	80.000000	0.170000	156.000000
75%	180.000000	0.300000	442.000000
max	12000.000000	1.000000	121900.000000

Year wise average total laid off and funds raised

In [153…

```
data.head()
```

Out[153]:

	company	location	industry	total_laid_off	percentage_laid_off	date	stage
0	N26	Berlin	Finance	71.0	0.04	2023-04-28	Series E
1	Providoor	Melbourne	Food	NaN	1.00	2023-04-28	Unknown
2	Dropbox	SF Bay Area	Other	500.0	0.16	2023-04-27	Post-IPO
3	Vroom	New York City	Transportation	120.0	0.11	2023-04-27	Post-IPO
4	Greenhouse	New York City	Recruiting	100.0	0.12	2023-04-27	Private Equity

Clean data - Remove Null Values, and Duplicated Items

In [154…

```
#Drop the rows where at least one element in a row is missing
no_null_data = data.dropna()

#Drop Duplicates
df = no_null_data.drop_duplicates()
print(df.shape)
df.head()
df.info()
```

```
(1165, 9)
<class 'pandas.core.frame.DataFrame'>
Int64Index: 1165 entries, 0 to 2541
Data columns (total 9 columns):
 #   Column              Non-Null Count  Dtype  
---  ------              --------------  -----  
 0   company             1165 non-null   object 
 1   location            1165 non-null   object 
 2   industry            1165 non-null   object 
 3   total_laid_off      1165 non-null   float64
 4   percentage_laid_off 1165 non-null   float64
 5   date                1165 non-null   object 
 6   stage               1165 non-null   object 
 7   country             1165 non-null   object 
 8   funds_raised        1165 non-null   float64
dtypes: float64(3), object(6)
memory usage: 91.0+ KB
```

Exploratory Data Analysis

In [155…

```
# Fixing Date's datatype
df_corr =df
df_corr['date'] = pd.to_datetime(df['date'])

# Adding a year column
df_corr["year"] = df['date'].dt.year
df_corr.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 1165 entries, 0 to 2541
Data columns (total 10 columns):
 #   Column              Non-Null Count  Dtype         
---  ------              --------------  -----         
 0   company             1165 non-null   object        
 1   location            1165 non-null   object        
 2   industry            1165 non-null   object        
 3   total_laid_off      1165 non-null   float64       
 4   percentage_laid_off 1165 non-null   float64       
 5   date                1165 non-null   datetime64[ns]
 6   stage               1165 non-null   object        
 7   country             1165 non-null   object        
 8   funds_raised        1165 non-null   float64       
 9   year                1165 non-null   int64         
dtypes: datetime64[ns](1), float64(3), int64(1), object(5)
memory usage: 100.1+ KB
```

```
/tmp/ipykernel_11621/1634207283.py:3: SettingWithCopyWarning:


A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs
/stable/user_guide/indexing.html#returning-a-view-versus-a-copy

/tmp/ipykernel_11621/1634207283.py:6: SettingWithCopyWarning:


A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs
/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
```

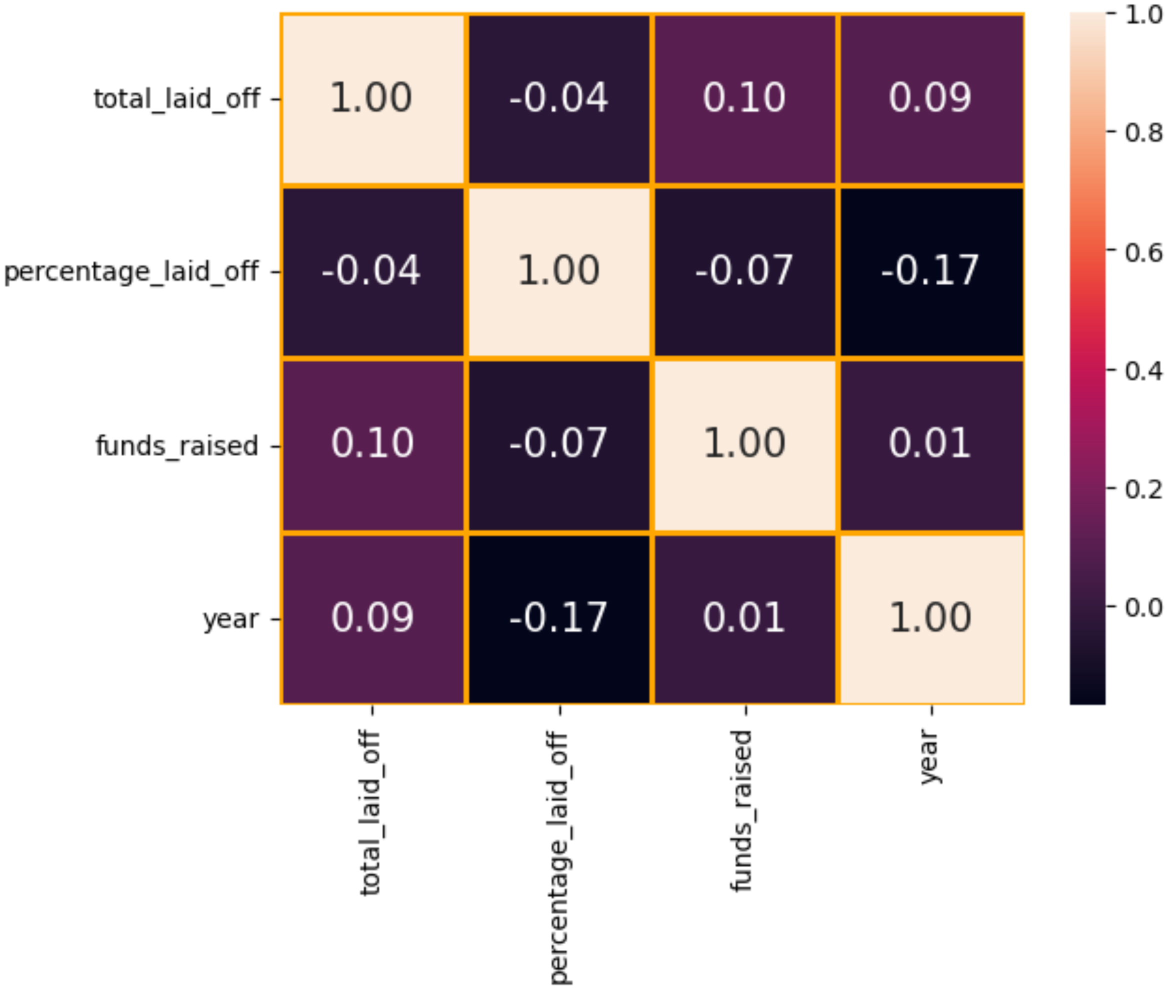
In [156…

```
#Correlation Analysis
#By using heatmap of the data for checking the correlation between the numer

sns.heatmap(df_corr.corr(), annot = True, fmt = '0.2f',
            annot_kws = {'size' : 15}, linewidth = 2, linecolor = 'orange')
```

```
/tmp/ipykernel_11621/1583328140.py:4: FutureWarning:

The default value of numeric_only in DataFrame.corr is deprecated. In a fut
ure version, it will default to False. Select only valid columns or specify
the value of numeric_only to silence this warning.
```

Out[156]:

```
<AxesSubplot: >
```

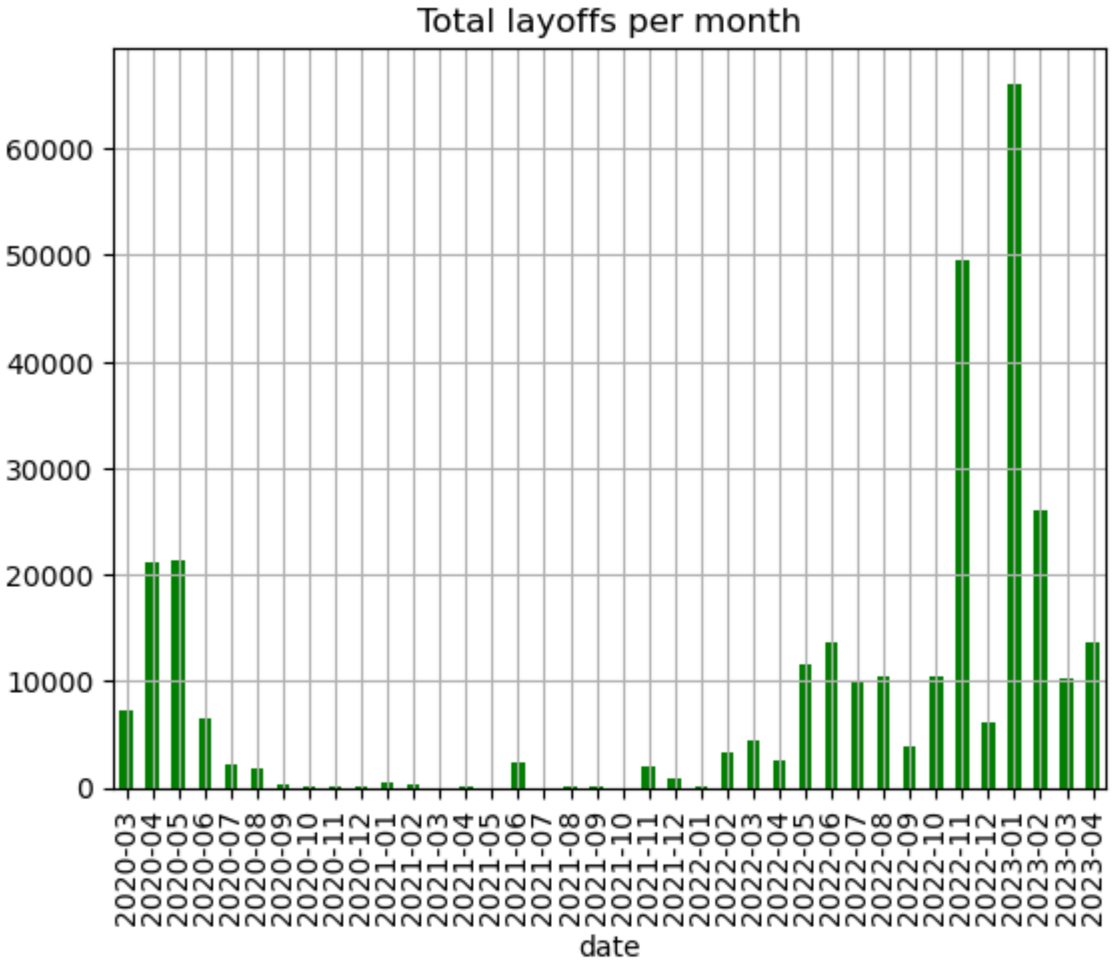


1. From above correlation figure we can say total laid off has strong correlation with year and funds raised.
2. Percentage_laid_off and funds raised has weak correlation.

In [157…

```
# By authors: Shreya Saha
#Group by month/Year
'''df = df[df['date'].notnull()].copy()
df['date'] = df['date'].astype('datetime64')
df.groupby(df['date'].dt.ye# Exploratory Data Analysisar).sum()
'''
## group date by months with the sum of all columns data (including total_la
## fillna(0): fill up missing bin or time with zero values (we assume zero m
df['date'] = pd.to_datetime(df['date'])
df1 = df.groupby(df['date'].dt.to_period('M')).sum(numeric_only=True)
df1 = df1.resample('M').asfreq().fillna(0)
df1['total_laid_off'].plot(kind='bar', grid = True, color = 'green', title =
/tmp/ipykernel_11621/2406948693.py:9: SettingWithCopyWarning:


A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs
/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
```

```
Out[157]: <AxesSubplot: title={'center': 'Total layoffs per month'}, xlabel='date'>
```



There are more recent mass layoffs between 2022 November and 2023 April than all other times combined.

```
In [158…  #Group by company
top_10 = df.groupby('company').sum().reset_index().sort_values(by='total_lai
top_10.head(4)
#top_10['total_laid_off'].plot(kind='barh', grid = True, title='Top 10 Compa
px.bar(top_10,x='company',y='total_laid_off',text='total_laid_off',title='To
      labels={'company':'Company','total_laid_off':'Total Lay-offs'})
```

```
/tmp/ipykernel_11621/4260994406.py:2: FutureWarning:

The default value of numeric_only in DataFrameGroupBy.sum is deprecated. In
a future version, numeric_only will default to False. Either specify numeri
c_only or select only columns which should be valid for the function.
```

In [159…

```
#Group by country
countrywise_laidoff = df.groupby(['country']).sum()
```

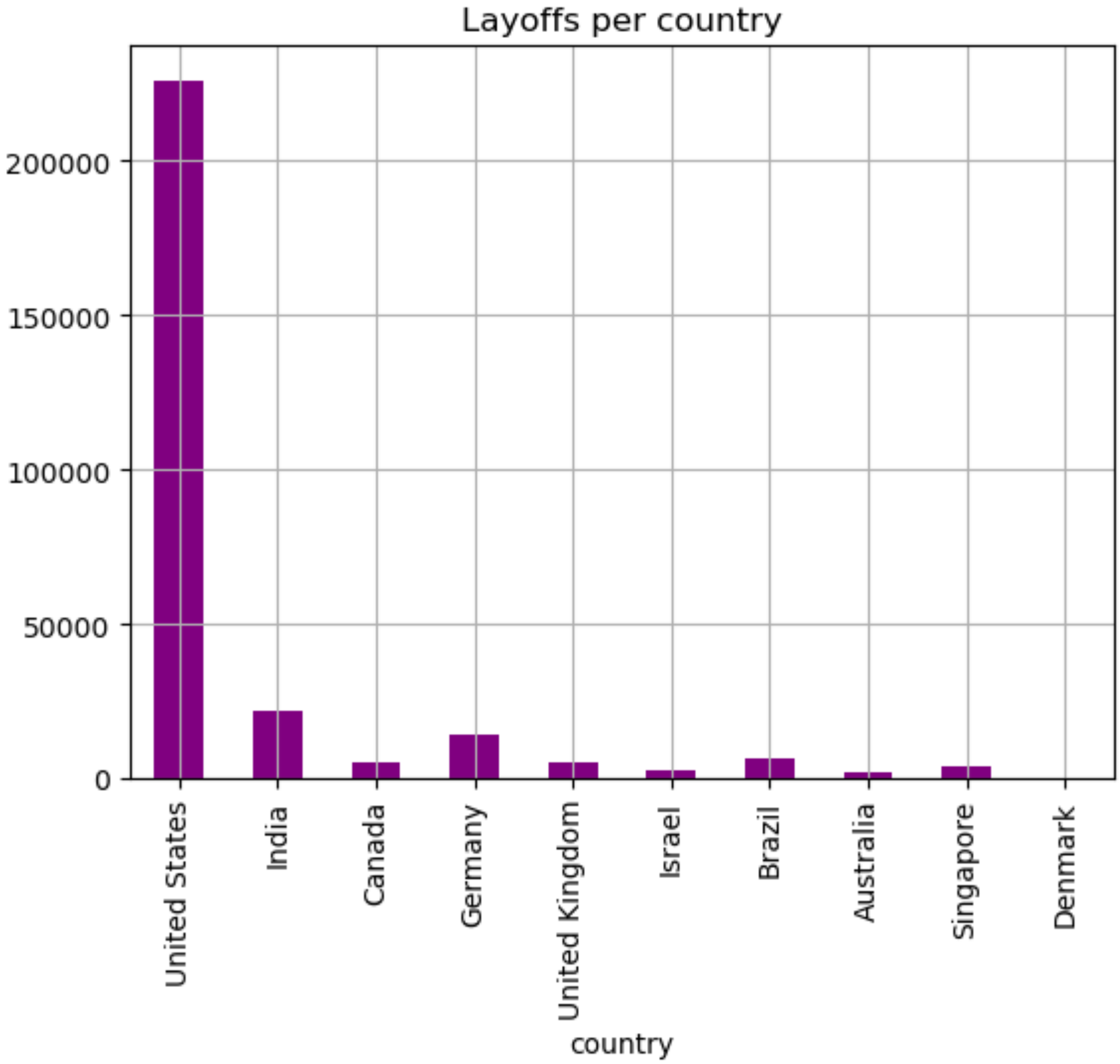
```
/tmp/ipykernel_11621/2007437147.py:2: FutureWarning:

The default value of numeric_only in DataFrameGroupBy.sum is deprecated. In
a future version, numeric_only will default to False. Either specify numeri
c_only or select only columns which should be valid for the function.
```

In [160…

```
countrywise = countrywise_laidoff.sort_values('percentage_laid_off',ascendin
countrywise['total_laid_off'].plot(kind = 'bar', color = 'purple', grid = Tr
```

Out[160]:

```
<AxesSubplot: title={'center': 'Layoffs per country'}, xlabel='country'>
```



The laid offs in United States is the highest, ~10 times more than the laid off in the second highest, India.

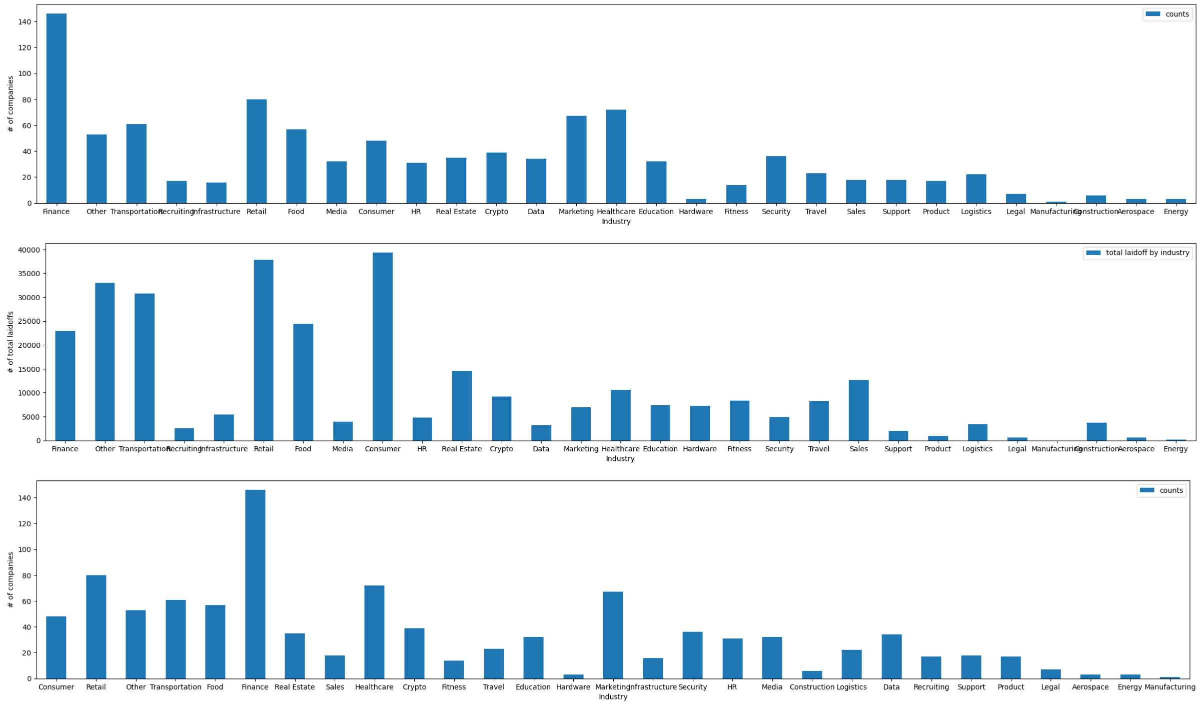
In [161…

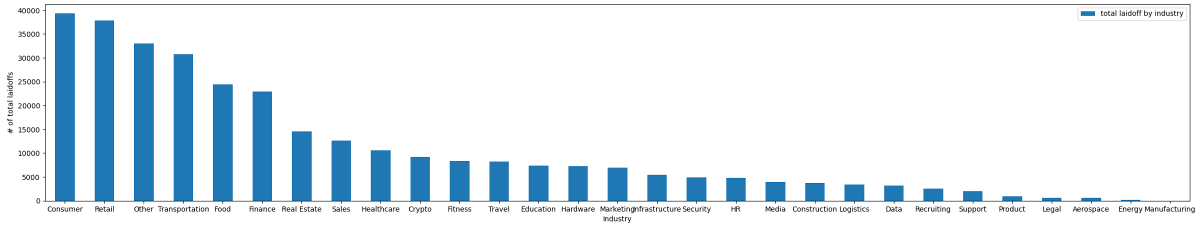
```
# By authors: Ya Huei Huang
## We plot two hisograms based on the type of industry; for each type of inc
## and the number of total laid off.
## We also sorted these two histogram by the nubmer of total laid off

l = df['industry'].unique()
n_bin = len(l)

print(l)

hist_industry = pd.DataFrame(0, index=np.arange(n_bin), columns=['industry_b

print(n_bin)
print(hist_industry.shape)

hist_industry['counts'].iloc[:]=0
hist_industry['total laidoff by industry'].iloc[:]=0

n = 0
a = []
for j in range(n_bin):
    n = 0
    for i in range(df.shape[0]):
        if df['industry'].iloc[i] == l[j]:
            n = n + 1
            a.append(df['company'].iloc[i])
            hist_industry['total laidoff by industry'].iloc[j]=hist_industry


    uniquelist = np.unique(a)
    hist_industry['industry_bin'].iloc[j]=l[j]
    hist_industry['counts'].iloc[j]=len(uniquelist)
    a[:] = []

# print(hist_industry.index)
# print(hist_industry['total laidoff by industry'].iloc[0:10])
sort_hist_industry = hist_industry.sort_values('total laidoff by industry',a


ax = hist_industry.plot.bar(x='industry_bin', y='counts', rot=0, figsize=(29
ax.set_xlabel('Industry')
ax.set_ylabel('# of companies')

ax1 = hist_industry.plot.bar(x='industry_bin', y='total laidoff by industry'
ax1.set_xlabel('Industry')
ax1.set_ylabel('# of total laidoffs')

ax3 = sort_hist_industry.plot.bar(x='industry_bin', y='counts', rot=0, figsi
ax3.set_xlabel('Industry')
ax3.set_ylabel('# of companies')

ax2 = sort_hist_industry.plot.bar(x='industry_bin', y='total laidoff by indu
ax2.set_xlabel('Industry')
ax2.set_ylabel('# of total laidoffs')

#companywise['counts'].plot(kind = 'bar', color = 'purple', grid = True, tit
#df_hardware = df[df['industry']=='Hardware']
#df_hardware.head(10)
#fig, ax = plt.subplots(figsize=(14,5))
#plt.plot(df_hardware.date, df_hardware.total_laid_off, 'b-', label="Total l
#ax.set_xlabel('Date')
#ax.set_ylabel('Total laid off')
#plt.title('Total laidoff by date (Hardware industry)')
```

```
['Finance' 'Other' 'Transportation' 'Recruiting' 'Infrastructure' 'Retail'
 'Food' 'Media' 'Consumer' 'HR' 'Real Estate' 'Crypto' 'Data' 'Marketing'
 'Healthcare' 'Education' 'Hardware' 'Fitness' 'Security' 'Travel' 'Sales'
 'Support' 'Product' 'Logistics' 'Legal' 'Manufacturing' 'Construction'
 'Aerospace' 'Energy']
29
(29, 3)
```

```
/tmp/ipykernel_11621/1472038813.py:32: SettingWithCopyWarning:


A value is trying to be set on a copy of a slice from a DataFrame

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs
/stable/user_guide/indexing.html#returning-a-view-versus-a-copy

/tmp/ipykernel_11621/1472038813.py:27: SettingWithCopyWarning:


A value is trying to be set on a copy of a slice from a DataFrame

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs
/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
```

```
Out[161]: Text(0, 0.5, '# of total laidoffs')
```





Consumer and retail industries have laid off >35000 employees, and the numbers of companies are ~50 and 80 respectively. On the other hand, Finance industry laid off ~22000 and has the highest number of different companies, ~140.

Example: USA's EDA

In [162…

```
# Since EDA for country vs laid off shows U.S. has laid off the highest numb
# we want to know what happened to the companies in U.S.A.
# Boxplot for USA
usa = df[df.country=='United States']
usa.shape
```

Out[162]:

```
(757, 10)
```

In [163…

```
l = usa['industry'].unique()
print(l)
```

```
['Finance' 'Other' 'Transportation' 'Recruiting' 'Infrastructure' 'Media'
 'HR' 'Real Estate' 'Crypto' 'Data' 'Healthcare' 'Consumer' 'Education'
 'Retail' 'Food' 'Fitness' 'Security' 'Travel' 'Sales' 'Hardware'
 'Support' 'Marketing' 'Product' 'Legal' 'Logistics' 'Manufacturing'
 'Aerospace' 'Construction' 'Energy']
```

In [164…

```
## Group by company in U.S.A.
usa_company = usa.groupby(["company"])
```

In [165…

```
## Create a histogram to calculate the composition of the laidoff by the num
max_laidoff_in_usa = usa_company['total_laid_off'].max().max()
min_laidoff_in_usa = usa_company['total_laid_off'].min().min()

print(max_laidoff_in_usa, min_laidoff_in_usa)

width_bin_laidoff = 100.0

n_bin = np.int64((max_laidoff_in_usa - min_laidoff_in_usa)/width_bin_laidoff

hist_laidoff_in_usa = pd.DataFrame(0, index=np.arange(n_bin), columns=['laid

print(n_bin)
print(hist_laidoff_in_usa.shape)
```

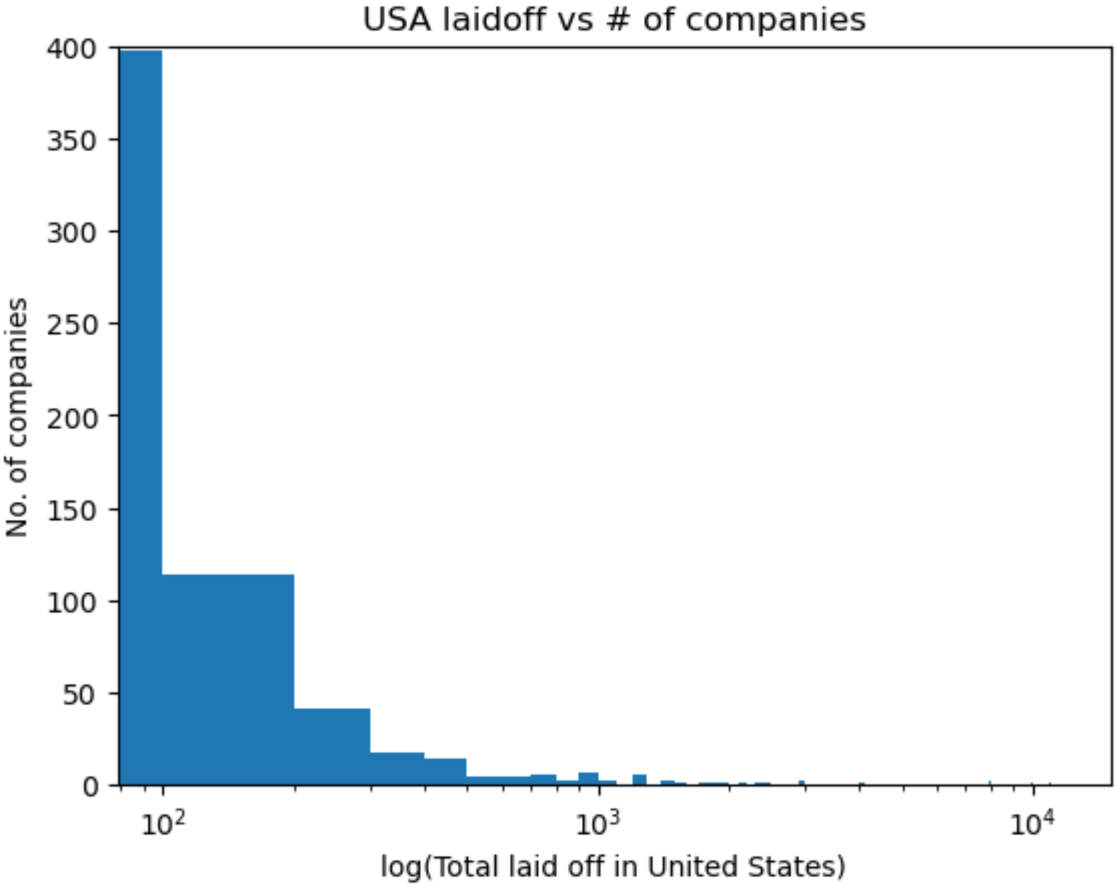
```
12000.0 3.0
119
(119, 2)
```

In [166…

```
## Create a log histogram and visualize the composition of the laidoff by th
hist_laidoff_in_usa['counts'].iloc[:]=0

for i in range(n_bin):
    value_bin = min_laidoff_in_usa + float(i+1)*width_bin_laidoff
    hist_laidoff_in_usa['laidoff_bin'].iloc[i] = value_bin

n = 0
for name, group in usa_company:
    n = n + 1
    n_group = group['total_laid_off'].shape

    for i in range(len(n_group)):

        value_in_group = group['total_laid_off'].values[i]

        for j in range(n_bin):

            bin_max = hist_laidoff_in_usa['laidoff_bin'].iloc[j]
            bin_min = bin_max - width_bin_laidoff

            if value_in_group > bin_min and value_in_group <= bin_max:
                hist_laidoff_in_usa['counts'].iloc[j] = hist_laidoff_in_usa[
                break


print(hist_laidoff_in_usa['counts'].tail(10))
print(hist_laidoff_in_usa['laidoff_bin'])

fig, ax = plt.subplots()

bins = np.arange(n_bin)
bins = bins * width_bin_laidoff
vals = np.zeros(n_bin)
vals = hist_laidoff_in_usa['counts'].iloc[:]
ax.bar(bins, vals, width=width_bin_laidoff, align='edge')
#ax.set_yscale('log')
ax.set_xscale('log')
ax.set_xlabel('log(Total laid off in United States)')
ax.set_ylabel('No. of companies')
#ax.set_xlim(3,20000)
ax.set_ylim(0,400)
plt.title('USA laidoff vs # of companies')
plt.show()
```

```
/tmp/ipykernel_11621/852341726.py:9: FutureWarning:

In a future version of pandas, a length 1 tuple will be returned when itera
ting over a groupby with a grouper equal to a list of length 1. Don't suppl
y a list with a single grouper to avoid this warning.
```

```
109    1
110    0
111    0
112    0
113    0
114    0
115    0
116    0
117    0
118    0
Name: counts, dtype: int64
0        103
1        203
2        303
3        403
4        503
       ...
114    11503
115    11603
116    11703
117    11803
118    11903
Name: laidoff_bin, Length: 119, dtype: int64
```



Analysis of relationship between total laid off and the number of companies in USA shows that few companies laid off more than 10000 employees, but more small scaled companies laid off the order of hundreds employees.

Task 1: Time series of mass layoffs

When did mass layoffs events occur? Is it time series a good model for predicting a future mass layoff?

By Author: Ya Huei Huang

Exploratory Data Analysis

1) Time series of mass layoffs dataset

In [167…

```
## Read in layoffs.csv again but with parse_dates option parsing the date
## in the common format to be compatiable with the stock market and COVID da

data_another = pd.read_csv("layoffs.csv",parse_dates=['date'])

#Drop the rows where at least one element in a row is missing
no_null_data_another = data_another.dropna()

#Drop Duplicates
df_another = no_null_data_another.drop_duplicates()
df_another.shape
df_another.head()

print(type(df_another['date'].iloc[0]),type(df['date'].iloc[0]))
```

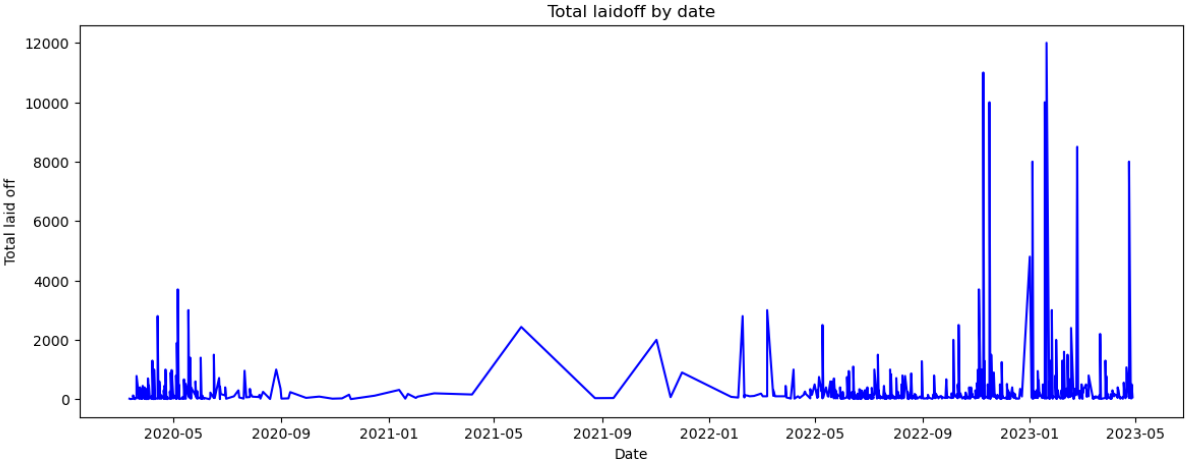
```
<class 'pandas._libs.tslibs.timestamps.Timestamp'> <class 'pandas._libs.tsl
ibs.timestamps.Timestamp'>
```

In [168…

```
fig, ax = plt.subplots(figsize=(14,5))

plt.plot(df_another.date, df_another.total_laid_off, 'b-', label="Total laid
ax.set_xlabel('Date')
ax.set_ylabel('Total laid off')
plt.title('Total laidoff by date')
```

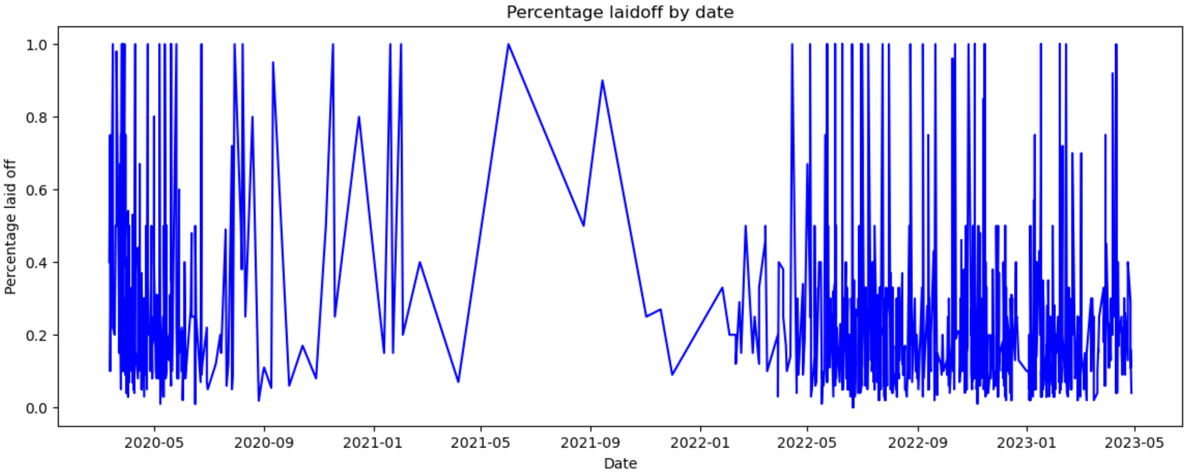
Out[168]:

```
Text(0.5, 1.0, 'Total laidoff by date')
```



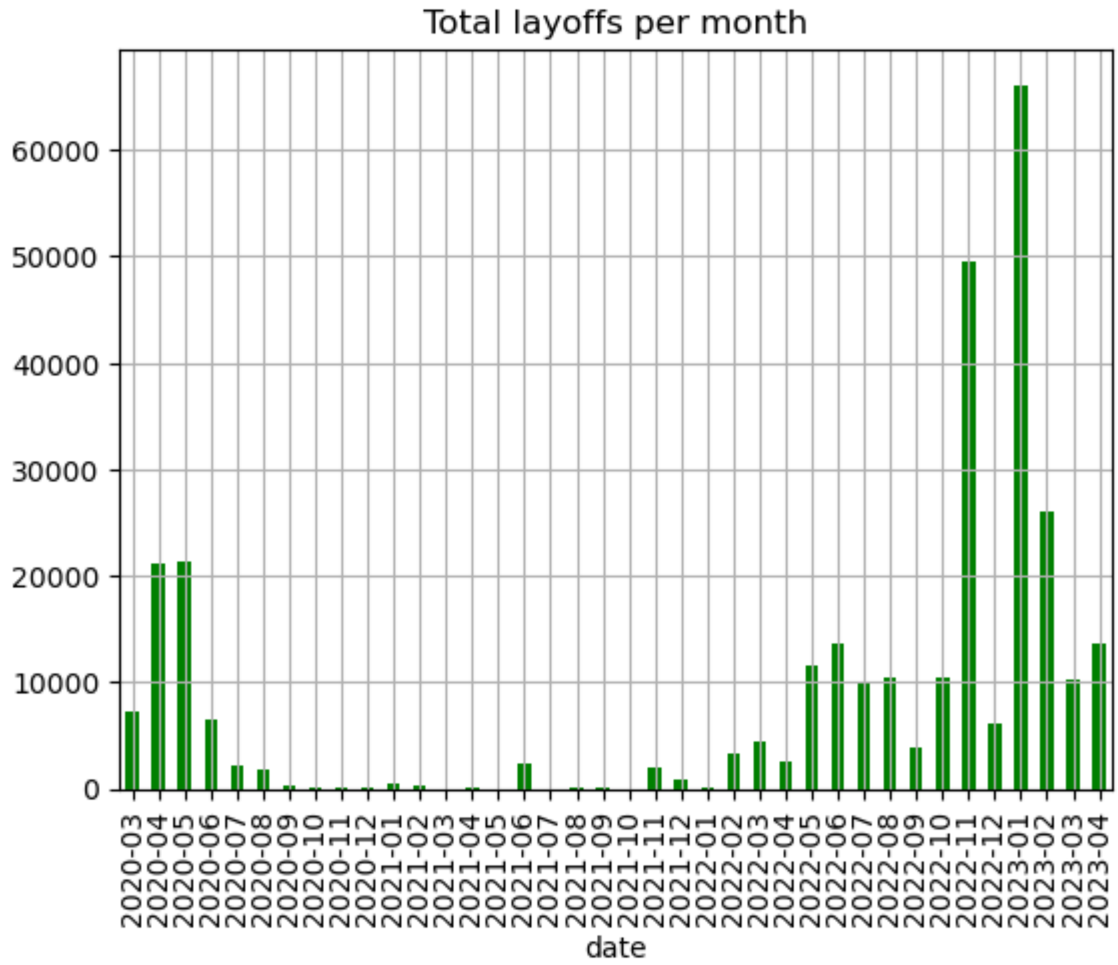
In [169…
```
fig, ax = plt.subplots(figsize=(14,5))

plt.plot(df_another.date, df_another.percentage_laid_off, 'b-', label="Perce
ax.set_xlabel('Date')
ax.set_ylabel('Percentage laid off')
plt.title('Percentage laidoff by date')
```

Out[169]:
```
Text(0.5, 1.0, 'Percentage laidoff by date')
```



In [170…
```
# We wanted to try time series analysis but realized there are either no lai
# So we decided to average the total laid off by a period of a month
# Total laid off per month using a part of the code from EDA by Shreya
df_another1 = df_another.groupby(df_another['date'].dt.to_period('M')).sum(n
df_another1_na = df_another1.resample('M').asfreq()
## We assume zero laid off for missing time 2021-03, 2021-05, 2021-07, and 2
df_another1 = df_another1.resample('M').asfreq().fillna(0)

print(df_another1_na.isna())
df_another1['total_laid_off'].plot(kind='bar', grid = True, color = 'green',
         total_laid_off  percentage_laid_off  funds_raised
date
2020-03           False                False         False
2020-04           False                False         False
2020-05           False                False         False
2020-06           False                False         False
2020-07           False                False         False
2020-08           False                False         False
2020-09           False                False         False
2020-10           False                False         False
2020-11           False                False         False
2020-12           False                False         False
2021-01           False                False         False
2021-02           False                False         False
2021-03            True                 True          True
2021-04           False                False         False
2021-05            True                 True          True
2021-06           False                False         False
2021-07            True                 True          True
2021-08           False                False         False
2021-09           False                False         False
2021-10            True                 True          True
2021-11           False                False         False
2021-12           False                False         False
2022-01           False                False         False
2022-02           False                False         False
2022-03           False                False         False
2022-04           False                False         False
2022-05           False                False         False
2022-06           False                False         False
2022-07           False                False         False
2022-08           False                False         False
2022-09           False                False         False
2022-10           False                False         False
2022-11           False                False         False
2022-12           False                False         False
2023-01           False                False         False
2023-02           False                False         False
2023-03           False                False         False
2023-04           False                False         False
```

```
Out[170]: <AxesSubplot: title={'center': 'Total layoffs per month'}, xlabel='date'>
```



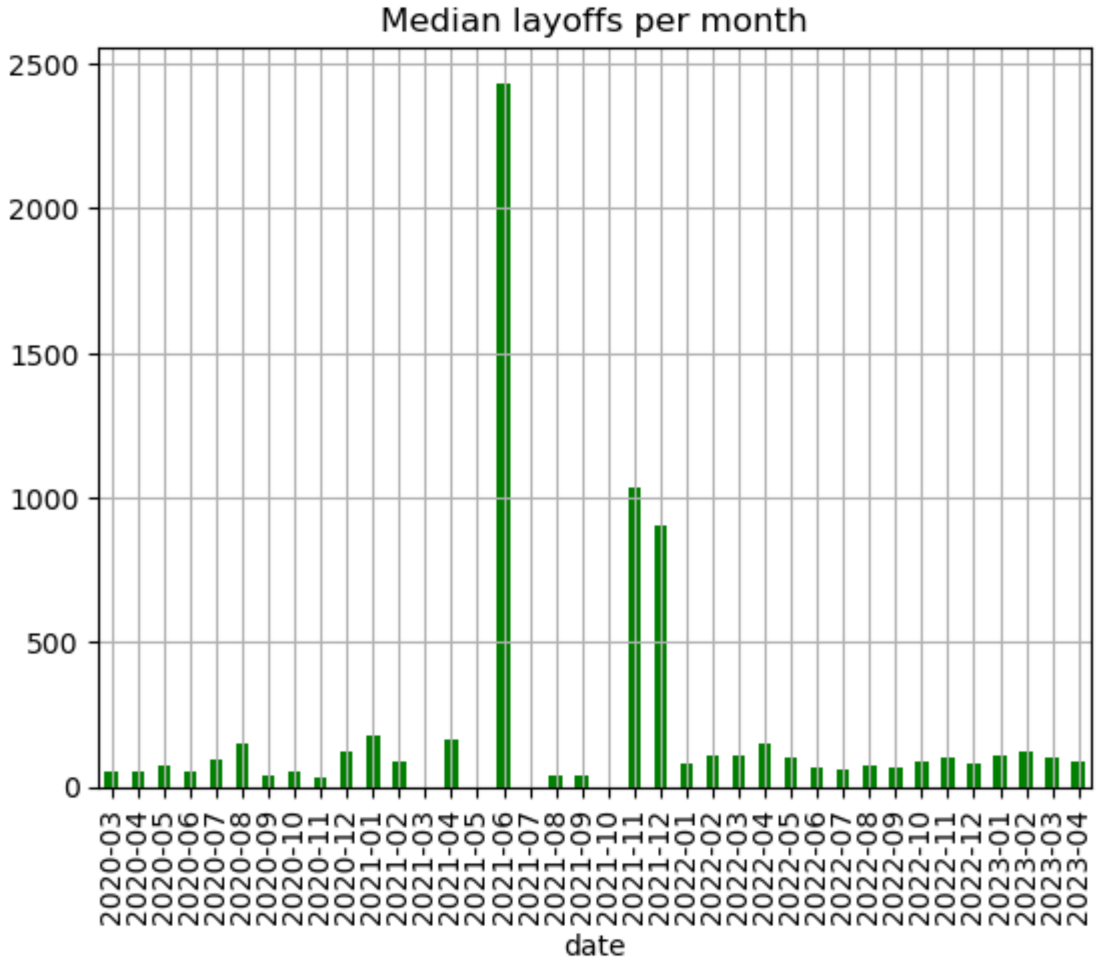
We have three missing months 2021-03, 2021-05, 2021-07, and 2021-10, which are not perfect but better than using date

In [171…

```
## Median laid off per month
df_another2 = df_another.groupby(df_another['date'].dt.to_period('M')).media
df_another = df_another2.resample('M').asfreq().fillna(0)
df_another2['total_laid_off'].plot(kind='bar', grid = True, color = 'green',
```

Out[171]:

```
<AxesSubplot: title={'center': 'Median layoffs per month'}, xlabel='date'>
```

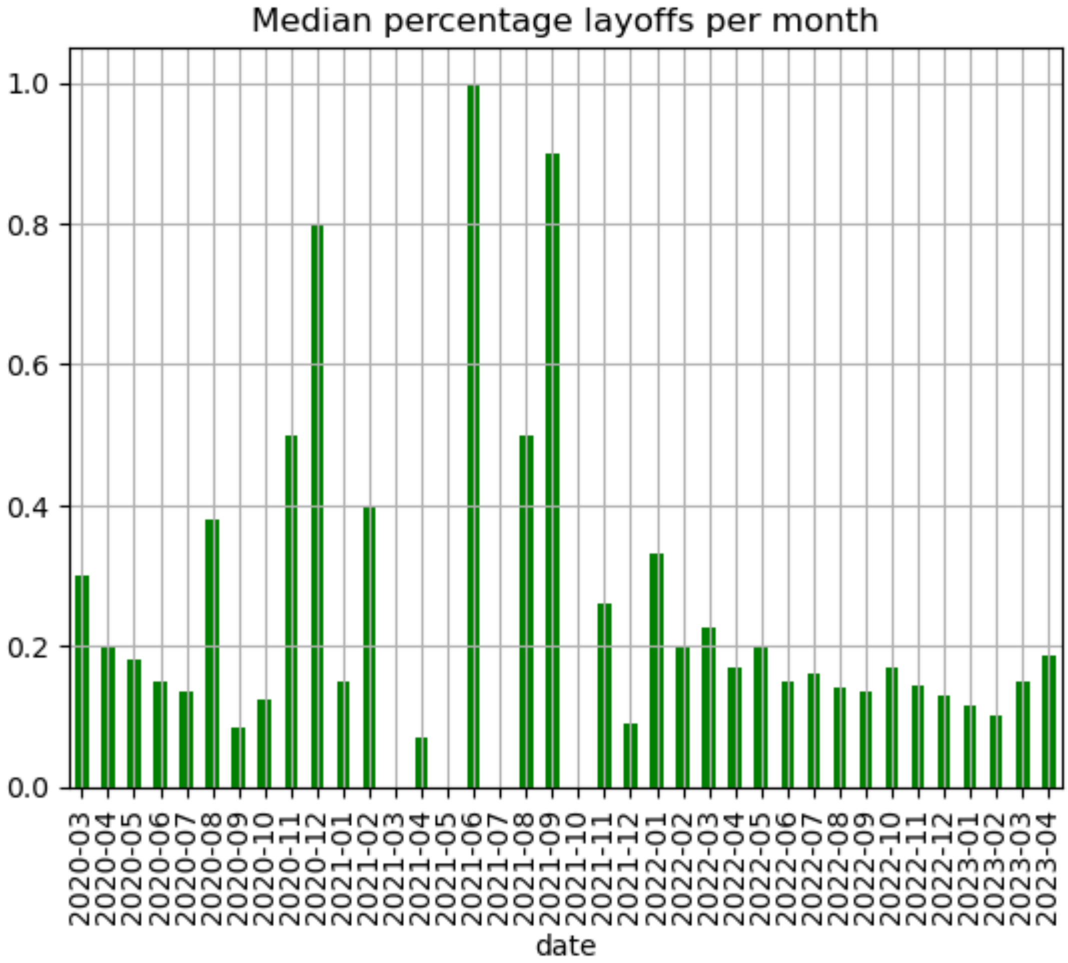


In [172…

```
## Median percentage laid off per month
df_another3 = df_another.groupby(df_another['date'].dt.to_period('M')).media
df_another3 = df_another3.resample('M').asfreq().fillna(0)
df_another3['percentage_laid_off'].plot(kind='bar', grid = True, color = 'gr
```

Out[172]:

```
<AxesSubplot: title={'center': 'Median percentage layoffs per month'}, xla
bel='date'>
```



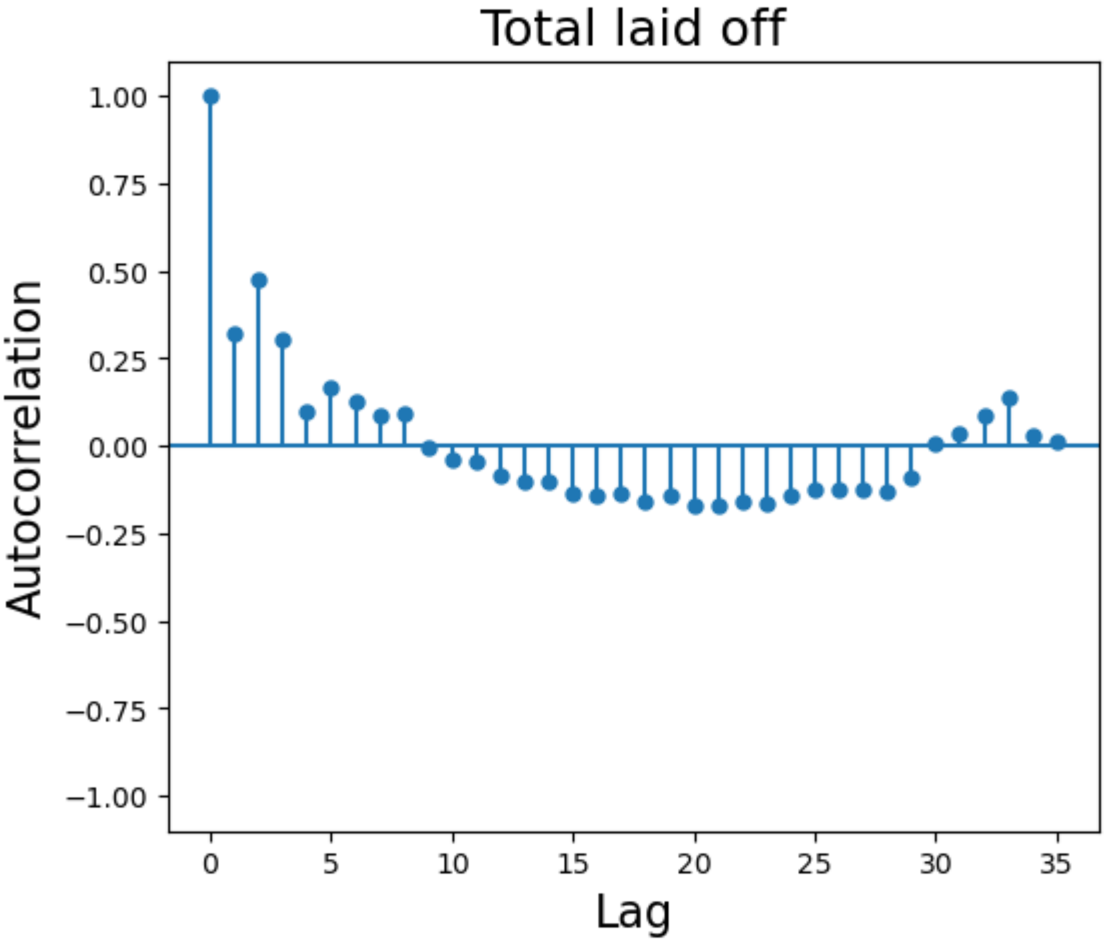
Autocorrelation and Stationarity

In [173…

```
# STATESMODEL Python package can be downloaded from https://www.statsmodels.
# statesmodel provides classes and function of different statical models
import statsmodels.api as sm
```

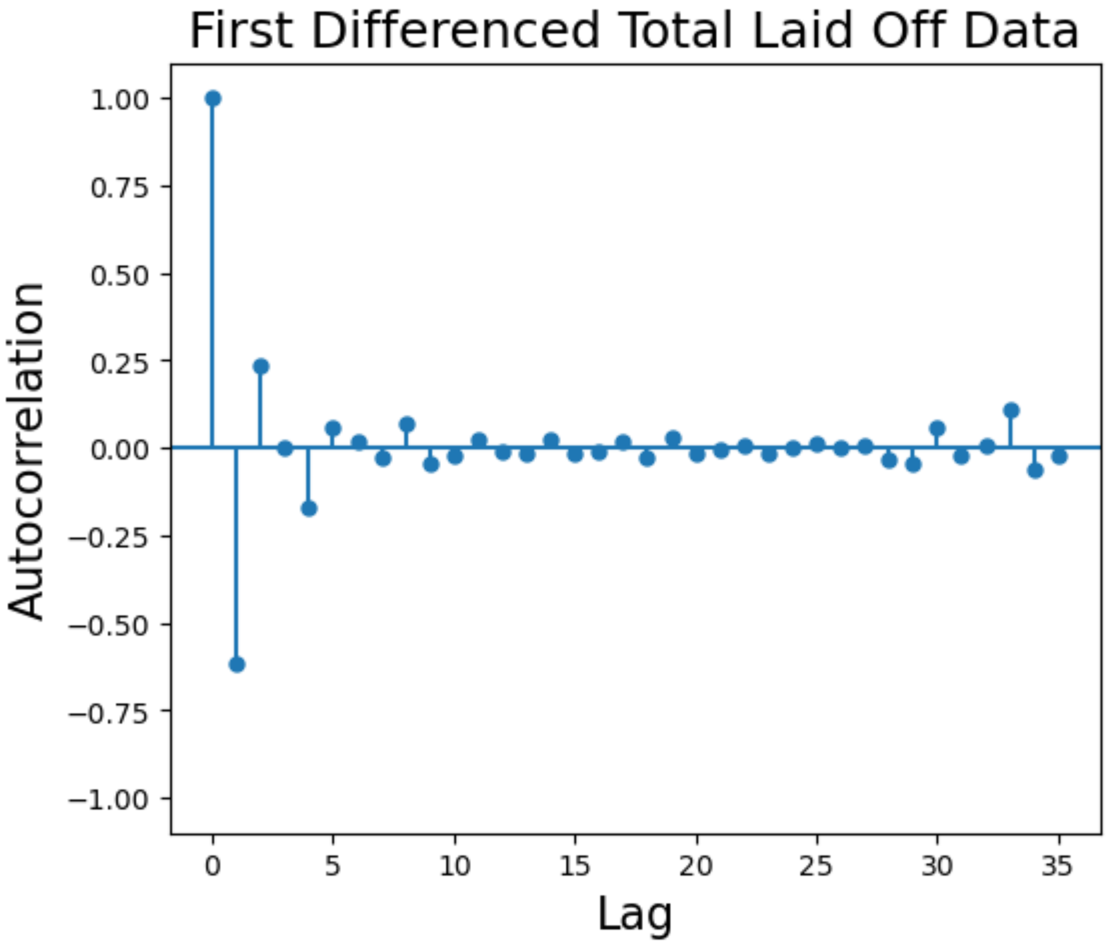
In [174…

```
fig, ax = plt.subplots(1, 1, figsize=(6,5))
sm.graphics.tsa.plot_acf(df_another1['total_laid_off'],
                         lags=35,
                         alpha=None,
                         ax=ax)

plt.title('Total laid off', fontsize=18)
plt.ylabel("Autocorrelation", fontsize=16)
plt.xlabel("Lag", fontsize=16)

plt.ylim(-1.1,1.1)

plt.show()
```



Our mentor, Nicole, at the Erdos Institute pointed out that a skewness of total laid off data (skewing more laid off in more recent time) might bias the autocorrelation plot here.

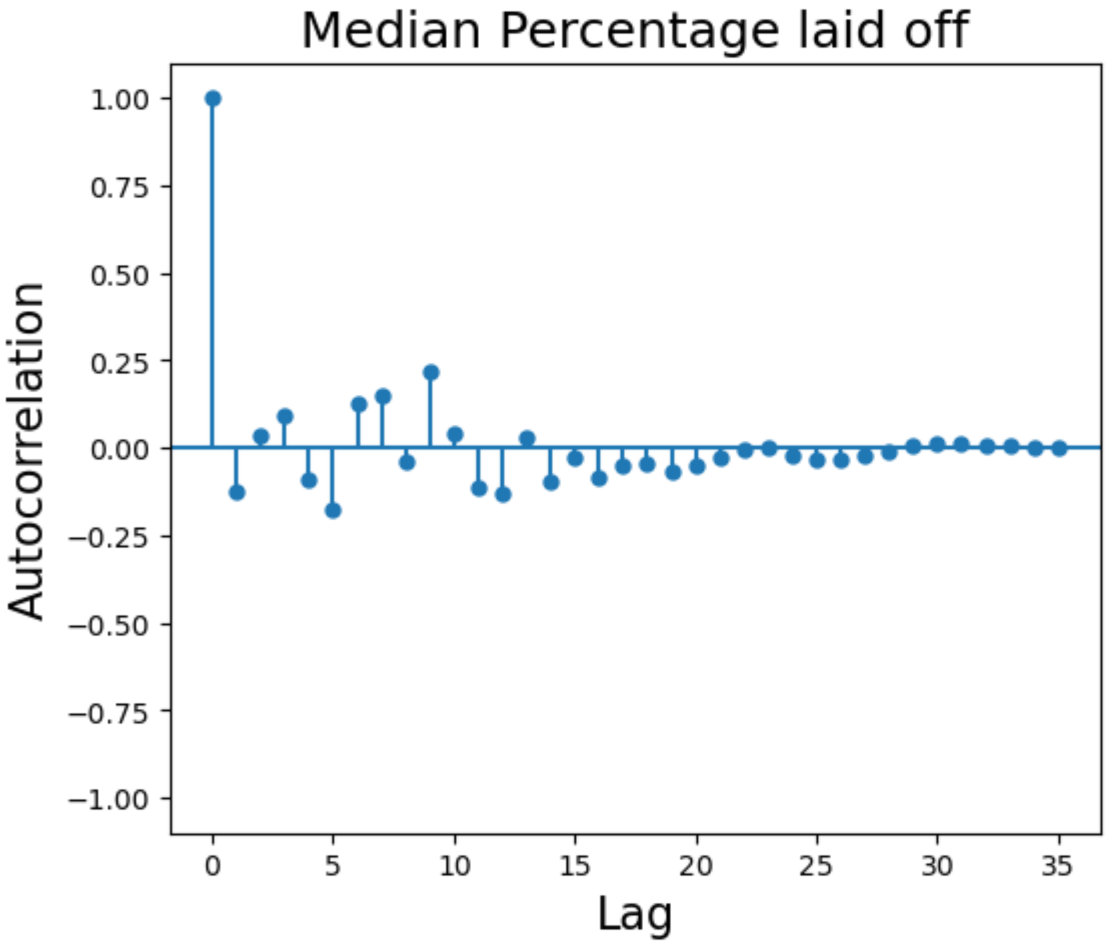
```
In [175…
# Differencing the total laid off data by time step of a month
# We want to see if there is particular trend
fig, ax = plt.subplots(1, 1, figsize=(6,5))

## use pandas .diff()
sm.graphics.tsa.plot_acf(df_another1['total_laid_off'].diff()[1:],
                         lags=35,
                         alpha=None,
                         ax=ax)

plt.title('First Differenced Total Laid Off Data', fontsize=18)
plt.ylabel("Autocorrelation", fontsize=16)
plt.xlabel("Lag", fontsize=16)

plt.ylim(-1.1,1.1)

plt.show()
```



The skewness of total laid off data appears to be still present

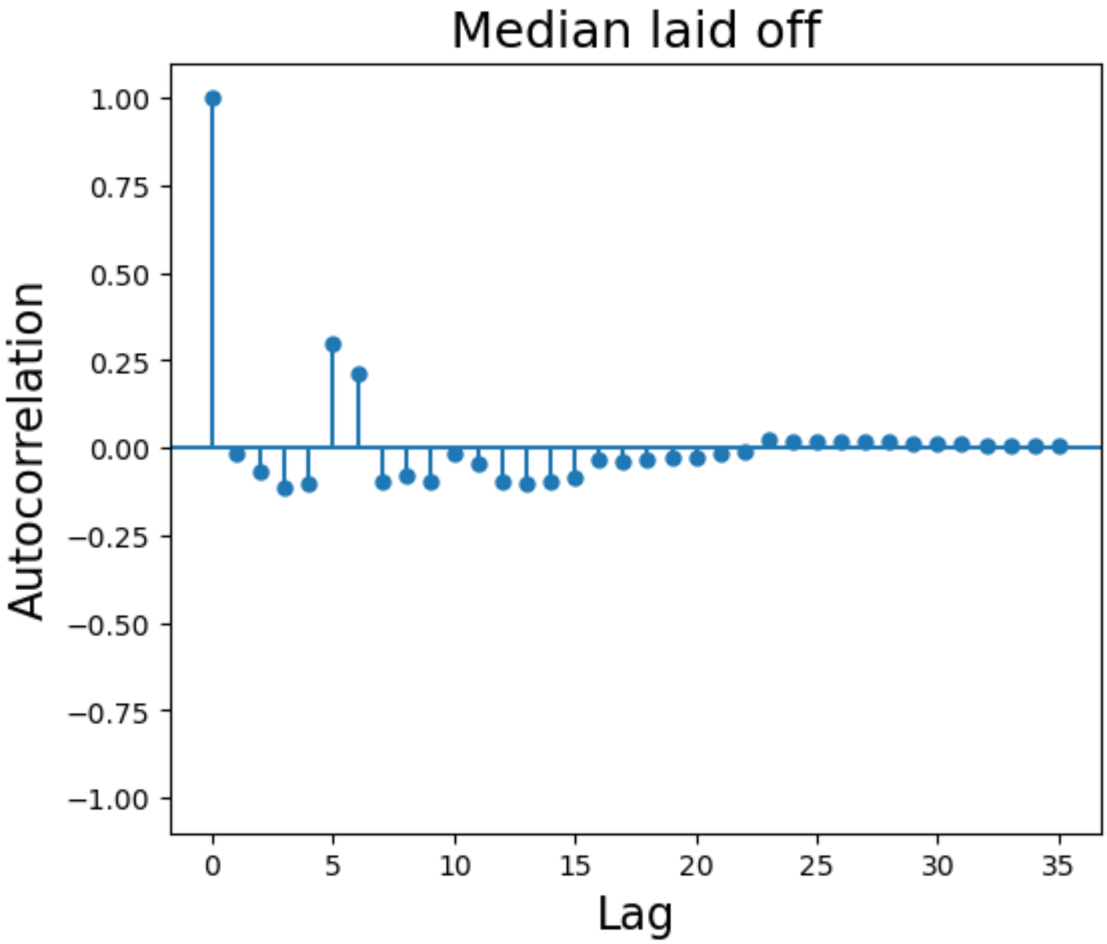
In [176…

```
fig, ax = plt.subplots(1, 1, figsize=(6,5))
sm.graphics.tsa.plot_acf(df_another3['percentage_laid_off'],
                         lags=35,
                         alpha=None,
                         ax=ax)

plt.title('Median Percentage laid off', fontsize=18)
plt.ylabel("Autocorrelation", fontsize=16)
plt.xlabel("Lag", fontsize=16)

plt.ylim(-1.1,1.1)

plt.show()
```



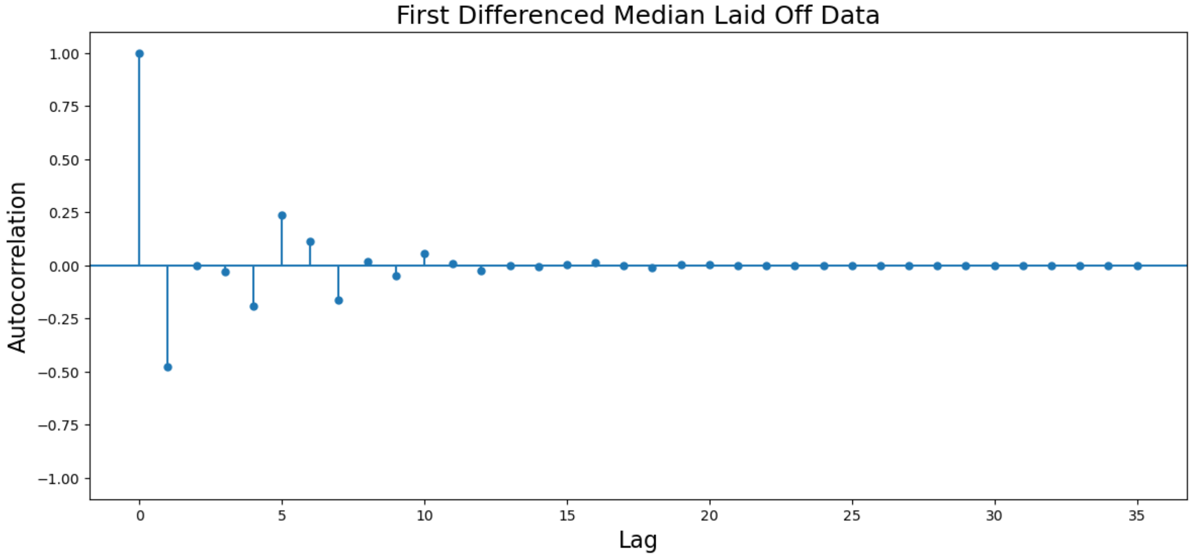
In [177…

```
fig, ax = plt.subplots(1, 1, figsize=(6,5))
sm.graphics.tsa.plot_acf(df_another2['total_laid_off'],
                         lags=35,
                         alpha=None,
                         ax=ax)

plt.title('Median laid off', fontsize=18)
plt.ylabel("Autocorrelation", fontsize=16)
plt.xlabel("Lag", fontsize=16)

plt.ylim(-1.1,1.1)

plt.show()
```



In [178…

```
fig, ax = plt.subplots(1, 1, figsize=(14,6))

## use pandas .diff()
sm.graphics.tsa.plot_acf(df_another2['total_laid_off'].diff()[1:],
                         lags=35,
                         alpha=None,
                         ax=ax)

plt.title('First Differenced Median Laid Off Data', fontsize=18)
plt.ylabel("Autocorrelation", fontsize=16)
plt.xlabel("Lag", fontsize=16)

plt.ylim(-1.1,1.1)

plt.show()
```



It seems it is tricky to interpret the time series data from autocorrelation plots, so we decide to "visual-inspect" the trends between mass layoffs and the other time-dependent data, such as stock market and COVID death cases.

2) S&P 500 dataset

In [179…

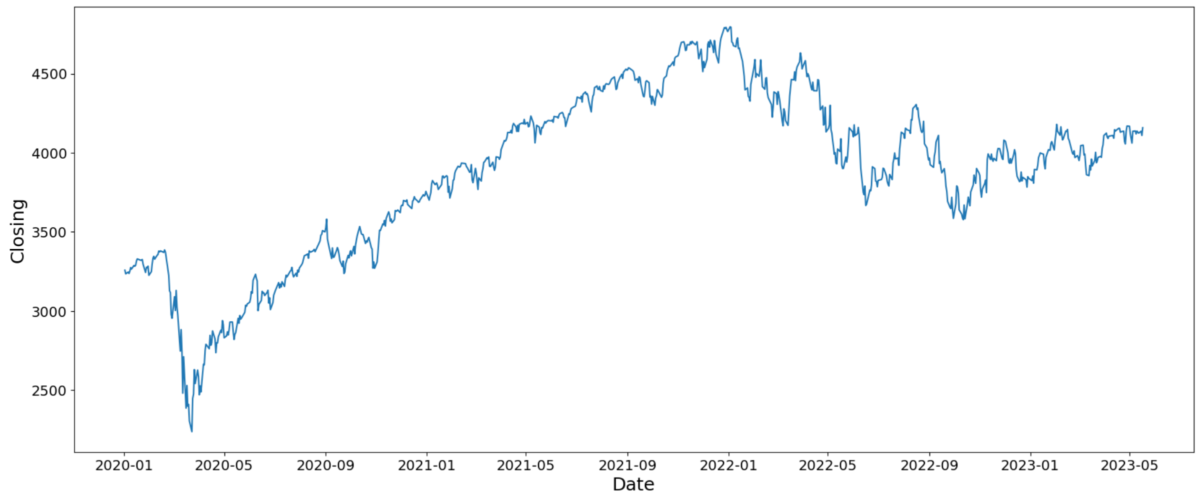
```
# We download S & P 500 USA stock market data from Kaggle.com
# https://www.kaggle.com/datasets/camnugent/sandp500?datasetId=1908&sortBy=v

# ''The datetime module supplies classes for manipulating dates and times.''
from datetime import datetime
sp = pd.read_csv("SP500.csv", parse_dates=['date'])
sp.head(2)
```

Out[179]:

	date	close	Volume	Open	High	Low
0	2023-05-17	4158.77	--	4122.85	4164.67	4113.62
1	2023-05-16	4109.90	--	4127.95	4135.54	4109.86

In [180…

```
plt.figure(figsize=(20,8))

plt.plot(sp.loc[sp.date >= datetime(2020,1,1)].date, sp.loc[sp.date >= datet

plt.xlabel("Date", fontsize=18)
plt.ylabel("Closing", fontsize=18)
plt.xticks(fontsize=14)
plt.yticks(fontsize=14)

plt.show()
```



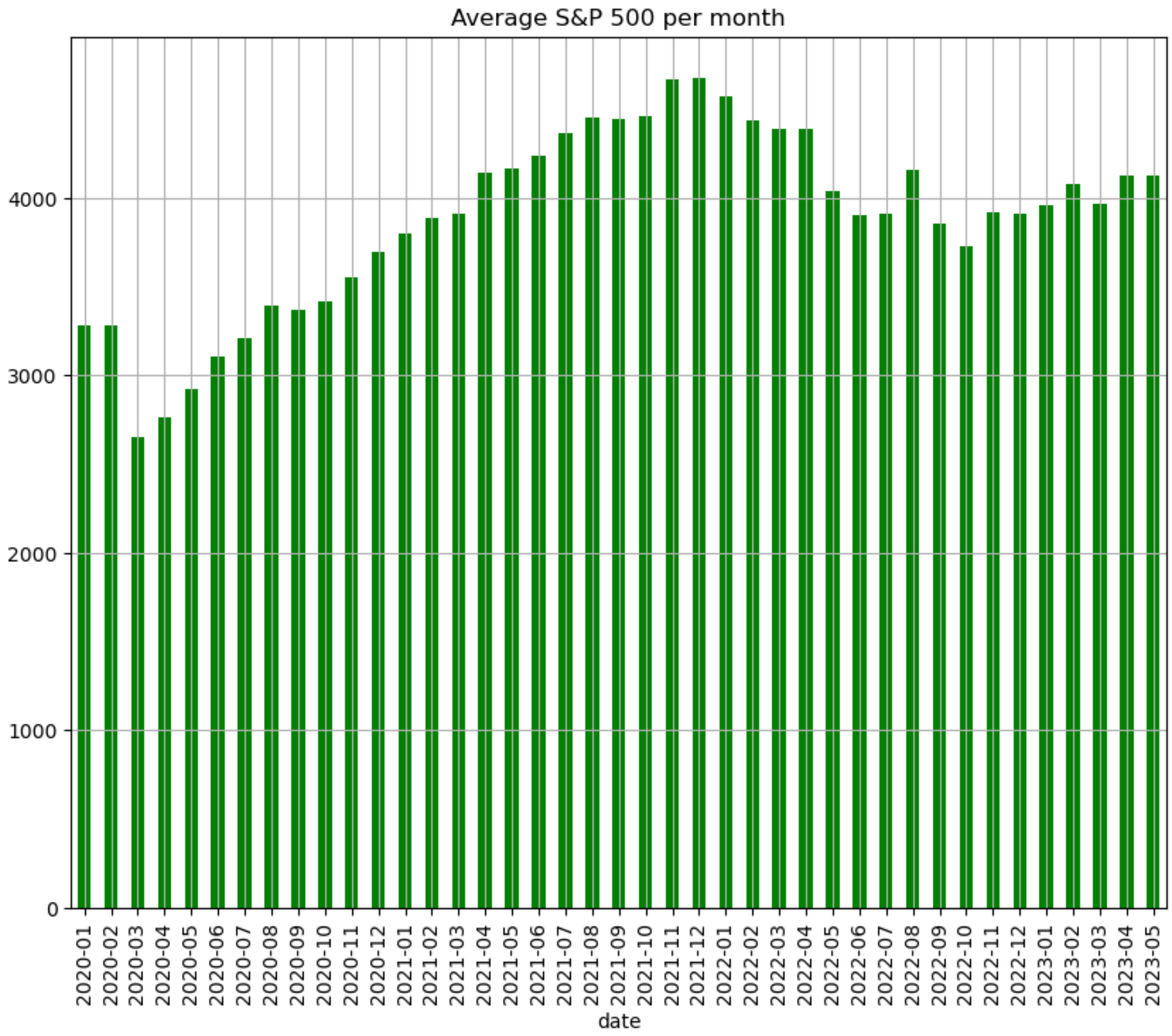
In [181…

```
sp_1 = sp[sp['date'] >= datetime(2020,1,1)]
sp1 = sp_1.groupby(sp_1['date'].dt.to_period('M')).mean()
sp1 = sp1.resample('M').asfreq().fillna(0)
plt.figure(figsize=(10,8))
sp1['close'].plot(kind='bar', grid = True, color = 'green', title = 'Average
```

```
/tmp/ipykernel_11621/2076382787.py:2: FutureWarning:

The default value of numeric_only in DataFrameGroupBy.mean is deprecated. I
n a future version, numeric_only will default to False. Either specify nume
ric_only or select only columns which should be valid for the function.
```

Out[181]:

```
<AxesSubplot: title={'center': 'Average S&P 500 per month'}, xlabel='date'
>
```



S&P 500 stock market appears to trend upward ...

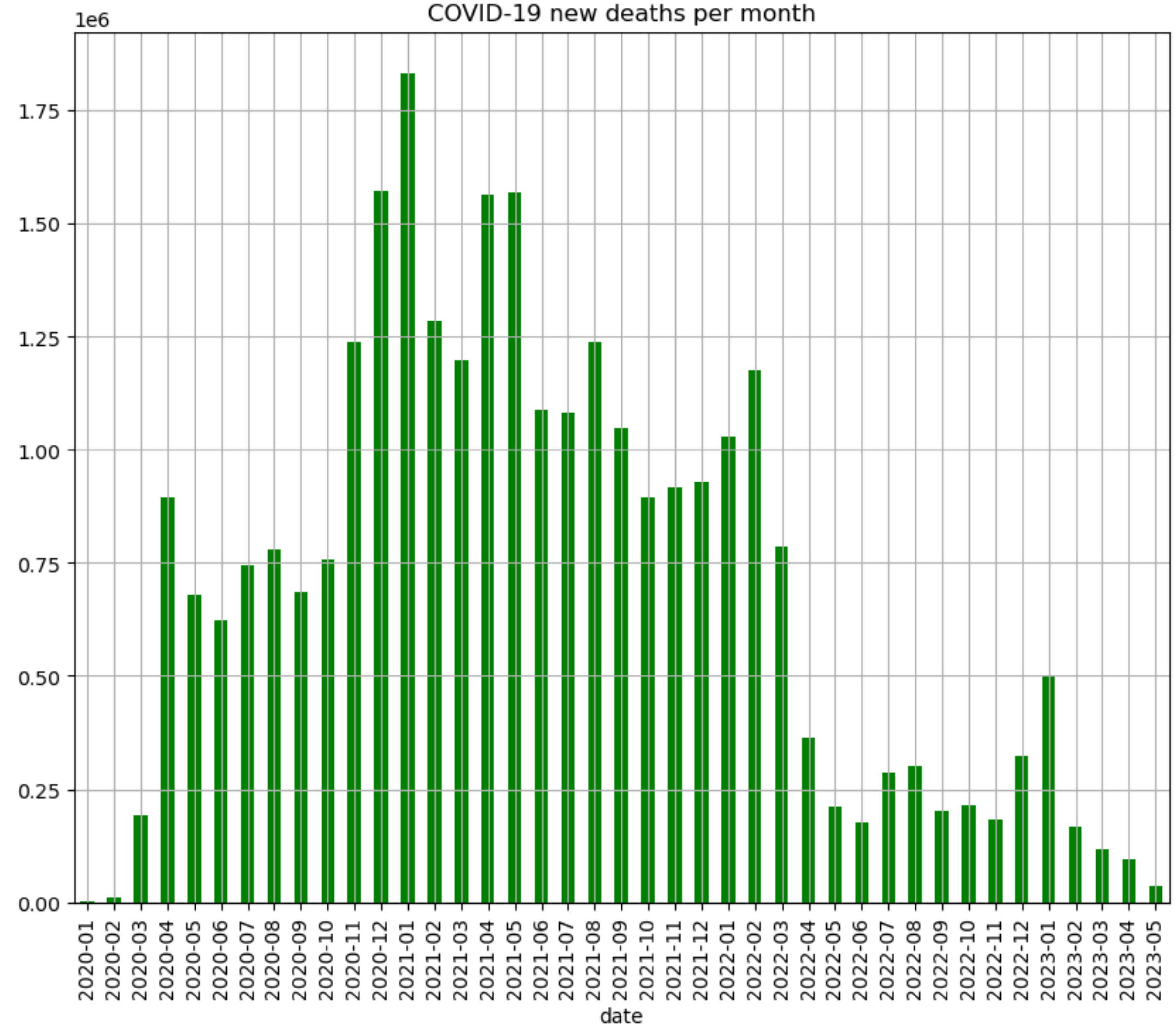
3) Time series of COVID19 dataset

In [182…

```
## COVID-19 data until recent time
## https://www.kaggle.com/datasets/taranvee/covid-19-dataset-till-2222022
covid19_1 = pd.read_csv('owid-covid-data.csv')
covid19_1.shape
list(covid19_1.columns.values)

covid19_1['date'] = pd.to_datetime(covid19_1['date'])
no_null_covid = covid19_1.dropna(subset=['date', 'new_deaths'])
no_null_data_covid =no_null_covid.drop_duplicates()
df_covid = no_null_data_covid.groupby(no_null_data_covid['date'].dt.to_perio
df_covid = df_covid.resample('M').asfreq().fillna(0)
plt.figure(figsize=(10,8))
df_covid['new_deaths'].plot(kind='bar', grid = True, color = 'green', title

#no_null_data_covid.shape
#Drop Duplicates
#df_covid = no_null_data_covid.drop_duplicates()
#df_covid.shape
```

```
/tmp/ipykernel_11621/2793909942.py:3: DtypeWarning:

Columns (33) have mixed types. Specify dtype option on import or set low_me
mory=False.

/tmp/ipykernel_11621/2793909942.py:10: FutureWarning:

The default value of numeric_only in DataFrameGroupBy.sum is deprecated. In
a future version, numeric_only will default to False. Either specify numeri
c_only or select only columns which should be valid for the function.
```

```
Out[182]: <AxesSubplot: title={'center': 'COVID-19 new deaths per month'}, xlabel='d
          ate'>
```



COVID deaths are higher between 2021 Nov and 2022 Feb than before 2021 Nov and after 2022 Feb.

Task 2: Linear Regression Model

By Author: Ya Huei Huang

As a predictive model, we want to predict the probability and number of laid-off based on a company's stage, industry type, stock market, country origin (related to GDP), and more things (not in this project) such as salary and demoncratic.

First, let's investigate if industry types have any impact on total laid offs

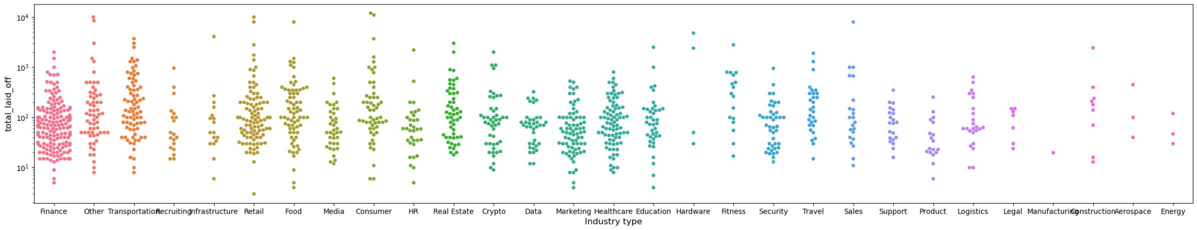
In [183…

```
#print(df.columns)

#industrywise = df.groupby(['industry'])
#print((industrywise))
#num_vars = ['age', 'fare']
#cat_vars = ['pclass', 'embarked', 'sex']

## Make a figure object
#plt.figure(figsize=(14,5))
fig, ax = plt.subplots(figsize=(29,5))

## Call swarmplot
## First put in the dataframe in data =
## Then what you want on the x and y axis
## Finally, palette, an optional input, allows me to color the points
sns.swarmplot(data=df_another,
               x = 'industry',
               y = 'total_laid_off',
            hue='industry',
            legend=False)

plt.xticks(fontsize=10)
plt.yticks(fontsize=10)
plt.xlabel("Industry type", fontsize=12)
plt.ylabel("total_laid_off", fontsize=12)
ax.set_yscale('log')

plt.show()
```

```
/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

83.3% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

55.7% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

53.2% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

36.8% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

35.3% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

70.1% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

60.9% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

68.4% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

51.9% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:
```

```
66.7% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

58.7% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

64.9% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

76.3% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

72.8% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

65.0% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

69.0% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

31.0% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

31.8% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

52.4% of the points cannot be placed; you may want to decrease the size of
```

```
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

44.4% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

37.5% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

19.0% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

5.2% of the points cannot be placed; you may want to decrease the size of t
he markers or use stripplot.
```



Let's investigate if stage have any impact on total laid offs

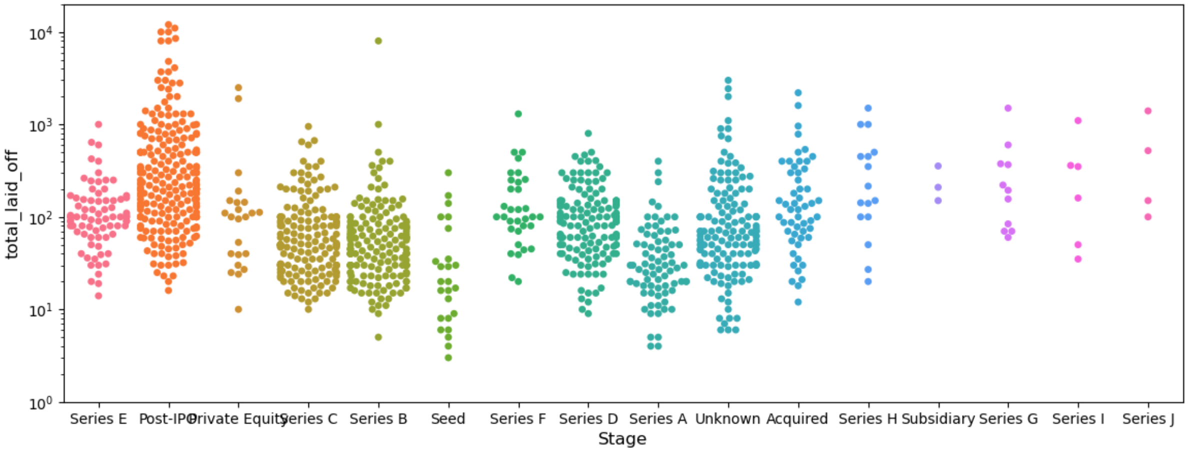
In [184…

```
fig, ax = plt.subplots(figsize=(14,5))

sns.swarmplot(data=df_another,
               x = 'stage',
               y = 'total_laid_off',
            hue='stage',
            legend=False)

plt.xticks(fontsize=10)
plt.yticks(fontsize=10)
plt.xlabel("Stage", fontsize=12)
plt.ylabel("total_laid_off", fontsize=12)
ax.set_yscale('log')
plt.ylim(1,20000)
plt.show()
```

```
/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

76.6% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

71.8% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

56.5% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

88.0% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

89.9% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

68.0% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

51.5% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

86.7% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

86.8% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:
```

```
83.8% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

62.3% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

12.5% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

19.5% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

31.2% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

29.7% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

36.7% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

25.9% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

6.6% of the points cannot be placed; you may want to decrease the size of t
he markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

21.8% of the points cannot be placed; you may want to decrease the size of
```

```
the markers or use stripplot.
```



For the observed total laid off data, it seems company stages show more variation of total laid off than in industry.

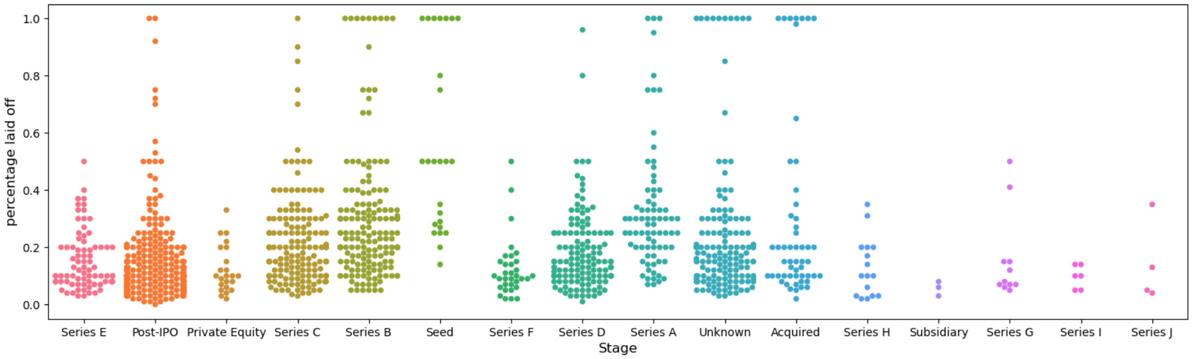
Let's investigate if stage have any impact on percentage laid offs

In [185…

```
fig, ax = plt.subplots(figsize=(18,5))

sns.swarmplot(data=df_another,
               x = 'stage',
               y = 'percentage_laid_off',
            hue='stage',
            legend=False)

plt.xticks(fontsize=10)
plt.yticks(fontsize=10)
plt.xlabel("Stage", fontsize=12)
plt.ylabel("percentage laid off", fontsize=12)
plt.show()
```

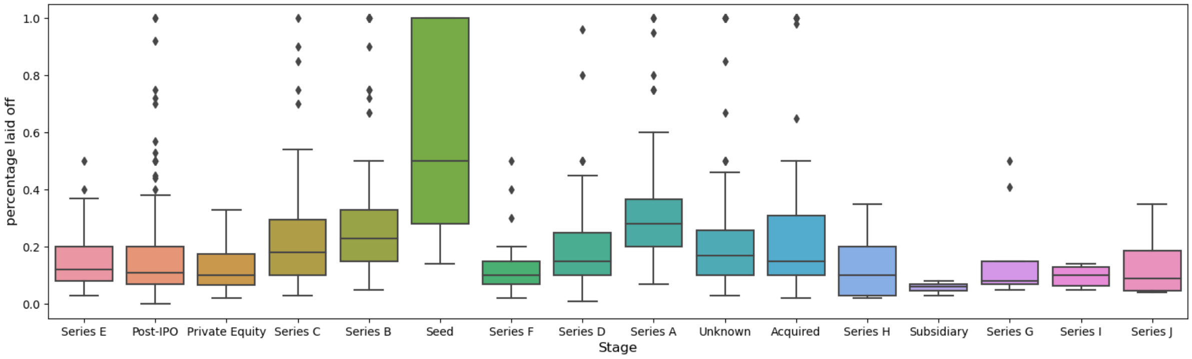
```
/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

10.4% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

34.2% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

20.3% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

17.8% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

17.0% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

14.8% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

33.3% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

19.0% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

16.0% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:
```

```
14.1% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

12.7% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.
```



In [186…

```
# We visualize the percentage laid off data using box plots
fig, ax = plt.subplots(figsize=(18,5))

sns.boxplot(data=df_another,
               x = 'stage',
               y = 'percentage_laid_off',
               hue='stage',
               dodge=False)

plt.xticks(fontsize=10)
plt.yticks(fontsize=10)
plt.xlabel("Stage", fontsize=12)
plt.ylabel("percentage laid off", fontsize=12)
plt.legend([],[], frameon=False)
plt.show()
```

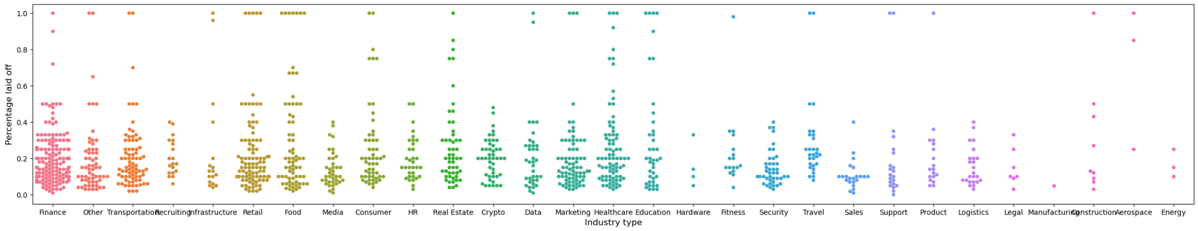


Let's investigate if industry have any impact on percentage laid offs

In [187…

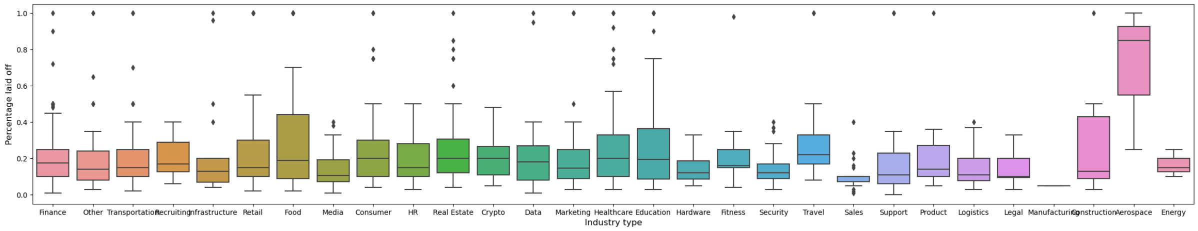
```
fig, ax = plt.subplots(figsize=(29,5))

sns.swarmplot(data=df_another,
                x = 'industry',
                y = 'percentage_laid_off',
             hue='industry',
             legend=False)

plt.xticks(fontsize=10)
plt.yticks(fontsize=10)
plt.xlabel("Industry type", fontsize=12)
plt.ylabel("Percentage laid off", fontsize=12)
plt.show()
```

```
/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

25.6% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

5.2% of the points cannot be placed; you may want to decrease the size of t
he markers or use stripplot.
```



In [188…

```
fig, ax = plt.subplots(figsize=(29,5))

## Call swarmplot
## First put in the dataframe in data =
## Then what you want on the x and y axis
## Finally, palette, an optional input, allows me to color the points
sns.boxplot(data=df_another,
                x = 'industry',
                y = 'percentage_laid_off',
                hue='industry',
                dodge=False)

plt.xticks(fontsize=10)
plt.yticks(fontsize=10)
plt.xlabel("Industry type", fontsize=12)
plt.ylabel("Percentage laid off", fontsize=12)
plt.legend([],[], frameon=False)
plt.show()
```



Now let's run linear regression model!

In [189…

```
# Pull tran test split function and linear regression from sklearn module
from sklearn.model_selection import train_test_split
from sklearn.linear_model import LinearRegression

laidoff_train, laidoff_test = train_test_split(df_another.copy(),
                                               shuffle=True,
                                               random_state=614,
                                               test_size=.2)
```

In [190…

```
dummy = pd.get_dummies(laidoff_train['stage']).columns
column_names = list(dummy)
print(column_names)
print(pd.get_dummies(laidoff_train['stage']).values)
print(pd.get_dummies(laidoff_train['stage']))
```

```
['Acquired', 'Post-IPO', 'Private Equity', 'Seed', 'Series A', 'Series B',
'Series C', 'Series D', 'Series E', 'Series F', 'Series G', 'Series H', 'Se
ries I', 'Series J', 'Subsidiary', 'Unknown']
[[1 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 0 ... 0 0 0]
 [0 0 0 ... 0 0 0]]
      Acquired  Post-IPO  Private Equity  Seed  Series A  Series B  Series
C  \
108          1         0               0     0         0         0
0
2342         0         0               0     0         0         1
0
976          0         0               0     0         0         0
0
1054         0         0               0     0         0         1
0
1009         0         0               0     0         0         1
0
...        ...       ...             ...   ...       ...       ...
...
1046         0         0               0     0         0         0
1
2234         0         0               0     0         0         0
1
2058         0         0               0     0         1         0
0
1320         1         0               0     0         0         0
0
286          0         0               0     0         0         1
0

      Series D  Series E  Series F  Series G  Series H  Series I  Series J
\
108          0         0         0         0         0         0         0
2342         0         0         0         0         0         0         0
976          0         1         0         0         0         0         0
1054         0         0         0         0         0         0         0
1009         0         0         0         0         0         0         0
...        ...       ...       ...       ...       ...       ...       ...
1046         0         0         0         0         0         0         0
2234         0         0         0         0         0         0         0
2058         0         0         0         0         0         0         0
1320         0         0         0         0         0         0         0
286          0         0         0         0         0         0         0

      Subsidiary  Unknown
108            0        0
2342           0        0
976            0        0
1054           0        0
1009           0        0
...          ...      ...
```

```
1046          0        0
2234          0        0
2058          0        0
1320          0        0
286           0        0

[932 rows x 16 columns]
```

In [191…

```
# We decide to do a linear regression model with percentage laid off, as we
# large number of laid off from a single or few companies

# Store the one-hot coding variable in laidoff_train here
# https://www.geeksforgeeks.org/how-to-get-column-names-in-pandas-dataframe/

laidoff_train.loc[:,pd.get_dummies(laidoff_train['stage']).columns] = pd.get
[pd.get_dummies(laidoff_train['stage']).columns]
```

```
/tmp/ipykernel_11621/244825464.py:7: DeprecationWarning:

In a future version, `df.iloc[:, i] = newvals` will attempt to set the valu
es inplace instead of always setting a new array. To retain the old behavio
r, use either `df[df.columns[i]] = newvals` or, if columns are non-unique,
`df.isetitem(i, newvals)`
```

Out[191]:

```
[Index(['Acquired', 'Post-IPO', 'Private Equity', 'Seed', 'Series A',
        'Series B', 'Series C', 'Series D', 'Series E', 'Series F', 'Serie
s G',
        'Series H', 'Series I', 'Series J', 'Subsidiary', 'Unknown'],
       dtype='object')]
```

There appears to be a trend between `stage` and `total laid off`. Our first two models will thus be the simple baseline and a simple linear regression regressing `total laid off` on `stage`.

Baseline model

$$\text{Laidoff} = E(\text{laidoff}) + \epsilon$$

Stage model

$$\text{Laidoff} = \beta_0 + \beta_{i>0}\text{stage\_\{i>0\}} + \epsilon$$

In [192…

```
## import mean_squared_error
from sklearn.metrics import mean_squared_error as mse
from sklearn import metrics #Import scikit-learn metrics module for accuracy
```

Model 1 &2: Use percentage of laid off

In [193…

```
## baseline model
mses1 = np.zeros((3, 1))

i = 0
pred_baseline1 = laidoff_train.percentage_laid_off.mean()*np.ones(len(laidof
mses1[0,i] = mse(laidoff_train.percentage_laid_off.values, pred_baseline1)

print(np.mean(mses1, axis=1)[0])

print("The average mse for the baseline model using percentage is",
                    np.round(np.mean(mses1, axis=1)[0],decimals =4))
```

```
0.04456357170047108
The average mse for the baseline model using percentage is 0.0446
```

In [194…

```
## stage model
## make the model object
## Use LInearRegression as our first model instance

stage_lr1 = LinearRegression(copy_X = True)

## make a list of column names, which is x axis as our independent measureme
## So, it is a multiple linear regression ("stage" one-hot encoding has 16 t
## https://sparkbyexamples.com/pandas/pandas-get-column-names/

print(laidoff_train[column_names].shape)
print(laidoff_train['percentage_laid_off'].shape)

## Fit the model
stage_lr1.fit(laidoff_train[column_names].values,
             laidoff_train['percentage_laid_off'].values)
```

```
(932, 16)
(932,)
```

Out[194]:

```
▾ LinearRegression

LinearRegression()
```

In [195…

```
# Predict percentage laid off from the train data sets
pred_stage_lr1 = stage_lr1.predict(laidoff_train[column_names].values)
```

In [196…

```
mses1[1,0] = mse(laidoff_train.percentage_laid_off.values, pred_stage_lr1)

print("The average mse for the stage model is",
                    np.round(np.mean(mses1, axis=1)[1],decimals =4))
```

```
The average mse for the stage model is 0.0381
```

In [197…

```
# Output the baseline and stage models' MSEs
print("The average mse for the stage model in train set is",
                    np.round(np.mean(mses1, axis=1)[1],decimals =4))
print("The average mse for the baseline model in train set is",
                    np.round(np.mean(mses1, axis=1)[0],decimals =4))
```

```
The average mse for the stage model in train set is 0.0381
The average mse for the baseline model in train set is 0.0446
```

In [198…

```
# Create a two dimension array to store 1) predicted percentage laid off by
print(laidoff_train.shape[0])
df_stage_lr1 = pd.DataFrame(0, index=np.arange(laidoff_train.shape[0]), colu

for i in range(laidoff_train.shape[0]):
    df_stage_lr1['stage'].iloc[i] = laidoff_train['stage'].iloc[i]

df_stage_lr1['pred_stage_lr1'] = pred_stage_lr1

print(df_stage_lr1.shape)
```

```
932
(932, 2)
```

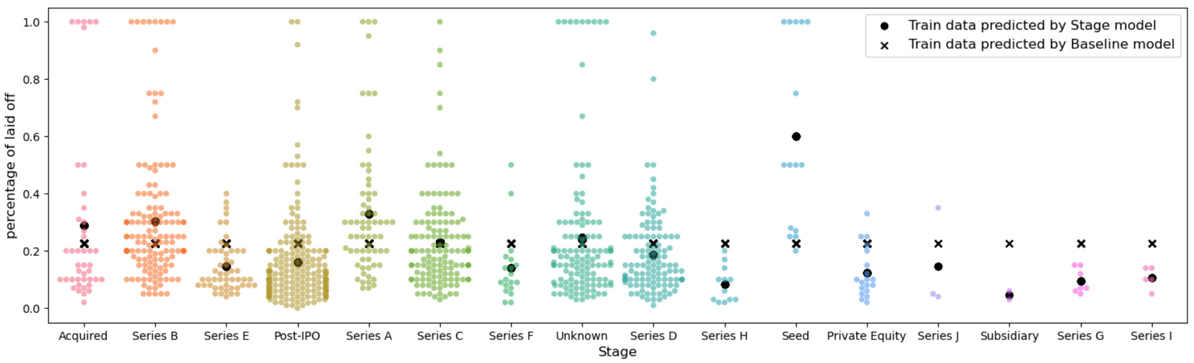
In [199…

```
# Create a two dimension array to store 1) predicted percentage laid off by
df_baseline1 = pd.DataFrame(0, index=np.arange(laidoff_train.shape[0]), colu

for i in range(laidoff_train.shape[0]):
    df_baseline1['stage'].iloc[i] = laidoff_train['stage'].iloc[i]

df_baseline1['pred_baseline1'] = pred_baseline1

print(df_baseline1.shape)
```

```
(932, 2)
```

In [200…

```
fig, ax = plt.subplots(figsize=(18,5))

plt.scatter(df_stage_lr1['stage'], df_stage_lr1['pred_stage_lr1'], c='black'

plt.scatter(df_baseline1['stage'], df_baseline1['pred_baseline1'], c='black'

sns.swarmplot(data=laidoff_train,
              x = 'stage',
              y = 'percentage_laid_off',
              hue='stage', alpha=0.6,
              legend=False)

plt.xlabel("Stage", fontsize=12)
plt.ylabel("percentage of laid off", fontsize=12)
plt.xticks(fontsize=10)
plt.yticks(fontsize=10)
plt.legend(fontsize=12)
plt.show()
#               order = ['Seed','Series A','Series B', 'Series C', 'Series
#                      'Series H', 'Series I', 'Series J','Acquired', 'Pos
#                      'Unknown'],
/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

14.4% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

25.7% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

12.5% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

12.3% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

9.8% of the points cannot be placed; you may want to decrease the size of t
he markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

24.6% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

10.9% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.

/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

6.2% of the points cannot be placed; you may want to decrease the size of t
he markers or use stripplot.
```



Create a dummy for test set

```
In [201…  laidoff_test.loc[:,pd.get_dummies(laidoff_test['stage']).columns] = pd.get_d
```

```
/tmp/ipykernel_11621/1995949124.py:1: DeprecationWarning:

In a future version, `df.iloc[:, i] = newvals` will attempt to set the valu
es inplace instead of always setting a new array. To retain the old behavio
r, use either `df[df.columns[i]] = newvals` or, if columns are non-unique,
`df.isetitem(i, newvals)`
```

Calculate regression's accuracy in R2 score (accuracy in regression model is captured ambiguously by R-squared)

- https://scikit-learn.org/stable/modules/classes.html#regression-metrics
- https://stackoverflow.com/questions/45627784/unable-to-obtain-accuracy-score-for-my-linear

```
In [202…  # Create Linear regression object
          clf = LinearRegression()

          # Train Linear regression model
          clf = clf.fit(laidoff_test[column_names].values,
                        laidoff_test['percentage_laid_off'].values)

          #Predict the response for test dataset
          y_test = laidoff_test['percentage_laid_off'].values.reshape(-1,1)
          y_pred = clf.predict(laidoff_test[column_names].values)
          y_pred = y_pred.reshape(-1,1)

          # We calculate coefficient of correlation for our predicted percentage laid
          # The higher the score (max =1), the more similar the y_test and y_pred valu
          # print("Variance score:",metrics.explained_variance_score(y_test, y_pred))

          print("R2 score: ", metrics.r2_score(y_test, y_pred))
```

```
R2 score:  0.21591274384861425
```

Model 3: Use percentage of laid off

Note: Industry model needs a bit more work as it seems that more missing, inconsistent data are present in train dataset and test dataset, and I don't think the changing random_state parameter would help this, so we cannot calculate R2 squared value for y_test and y_pred. This model wouldn't go into the final presentation.

In [203…

```
laidoff_train, laidoff_test = train_test_split(df_another.copy(),
                                               shuffle=True,
                                               random_state=614,
                                               test_size=.2)

dummy1 = pd.get_dummies(laidoff_train['industry']).columns
column_names1 = list(dummy1)

dummy2 = pd.get_dummies(laidoff_test['industry']).columns
column_names2 = list(dummy2)
#print(pd.get_dummies(laidoff_train['company']).values)
#print(pd.get_dummies(laidoff_train['company']))

print(column_names1)
print(column_names2)
```

```
['Aerospace', 'Construction', 'Consumer', 'Crypto', 'Data', 'Education', 'E
nergy', 'Finance', 'Fitness', 'Food', 'HR', 'Hardware', 'Healthcare', 'Infr
astructure', 'Legal', 'Logistics', 'Manufacturing', 'Marketing', 'Media', '
Other', 'Product', 'Real Estate', 'Recruiting', 'Retail', 'Sales', 'Securit
y', 'Support', 'Transportation', 'Travel']
['Aerospace', 'Construction', 'Consumer', 'Crypto', 'Data', 'Education', 'E
nergy', 'Finance', 'Fitness', 'Food', 'HR', 'Hardware', 'Healthcare', 'Infr
astructure', 'Legal', 'Logistics', 'Marketing', 'Media', 'Other', 'Product
', 'Real Estate', 'Recruiting', 'Retail', 'Sales', 'Security', 'Support', '
Transportation', 'Travel']
```

In [204…

```
laidoff_train.loc[:,pd.get_dummies(laidoff_train['industry']).columns] = pd.
```

```
/tmp/ipykernel_11621/148286116.py:1: DeprecationWarning:

In a future version, `df.iloc[:, i] = newvals` will attempt to set the valu
es inplace instead of always setting a new array. To retain the old behavio
r, use either `df[df.columns[i]] = newvals` or, if columns are non-unique,
`df.isetitem(i, newvals)`
```

In [205…

```
## industry model
## make the model object
## Use LInearRegression as our first model instance

industry_lr1 = LinearRegression(copy_X = True)

## make a list of column names, which is x axis as our independent measureme
## So, it is a multiple linear regression ("stage" one-hot encoding has 16 t
## https://sparkbyexamples.com/pandas/pandas-get-column-names/

print(laidoff_train['percentage_laid_off'].shape)

## Fit the model
industry_lr1.fit(laidoff_train[column_names1].values,
             laidoff_train['percentage_laid_off'].values)
```

```
(932,)
```

Out[205]:

```
▾ LinearRegression

LinearRegression()
```

In [206…

```
pred_industry_lr1 = industry_lr1.predict(laidoff_train[column_names1].values
```

In [207…

```
mses1[2,0] = mse(laidoff_train.percentage_laid_off.values, pred_industry_lr1

print("The average mse for the industry model using percentage is",
                    np.round(np.mean(mses1, axis=1)[2],decimals =4))
```

```
The average mse for the industry model using percentage is 0.0421
```

In [208…

```
df_industry_lr1 = pd.DataFrame(0, index=np.arange(laidoff_train.shape[0]), c

for i in range(laidoff_train.shape[0]):
    df_industry_lr1['industry'].iloc[i] = laidoff_train['industry'].iloc[i]

df_industry_lr1['pred_industry_lr1'] = pred_industry_lr1

print(df_industry_lr1.shape)
```

```
(932, 2)
```

In [209…

```
pred_baseline2 = laidoff_train.percentage_laid_off.mean()*np.ones(len(laidof
mses1[0,0] = mse(laidoff_train.percentage_laid_off.values, pred_baseline2)

print(np.mean(mses1, axis=1)[0])

print("The average mse for the baseline model using percentage is",
                    np.round(np.mean(mses1, axis=1)[0],decimals =4))

df_baseline2 = pd.DataFrame(0, index=np.arange(laidoff_train.shape[0]), colu

for i in range(laidoff_train.shape[0]):
    df_baseline2['industry'].iloc[i] = laidoff_train['industry'].iloc[i]

df_baseline2['pred_baseline2'] = pred_baseline2

print(df_baseline2.shape)
```

```
0.04456357170047108
The average mse for the baseline model using percentage is 0.0446
(932, 2)
```

In [210…

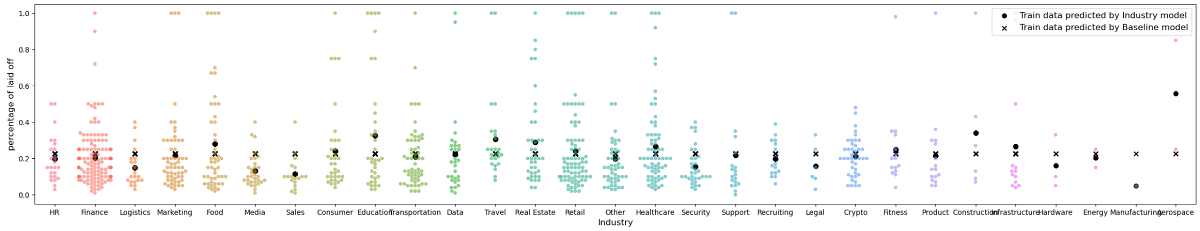
```
print("The average mse for the baseline model using percentage is",
                    np.round(np.mean(mses1, axis=1)[0],decimals =4))
print("The average mse for the industry model using percentage is",
                    np.round(np.mean(mses1, axis=1)[2],decimals =4))
```

```
The average mse for the baseline model using percentage is 0.0446
The average mse for the industry model using percentage is 0.0421
```

In [211…

```
fig, ax = plt.subplots(figsize=(29,5))

plt.scatter(df_industry_lr1['industry'], df_industry_lr1['pred_industry_lr1'

plt.scatter(df_baseline2['industry'], df_baseline2['pred_baseline2'], c='bla

sns.swarmplot(data=laidoff_train,
               x = 'industry',
               y = 'percentage_laid_off',
              hue='industry', alpha=0.6,
              legend=False)

plt.xlabel("Industry", fontsize=12)
plt.ylabel("percentage of laid off", fontsize=12)
plt.xticks(fontsize=10)
plt.yticks(fontsize=10)
plt.legend(fontsize=12)
plt.show()
```

```
/home/yahuei/anaconda3/envs/py3.8/lib/python3.8/site-packages/seaborn/categ
orical.py:3544: UserWarning:

21.6% of the points cannot be placed; you may want to decrease the size of
the markers or use stripplot.
```

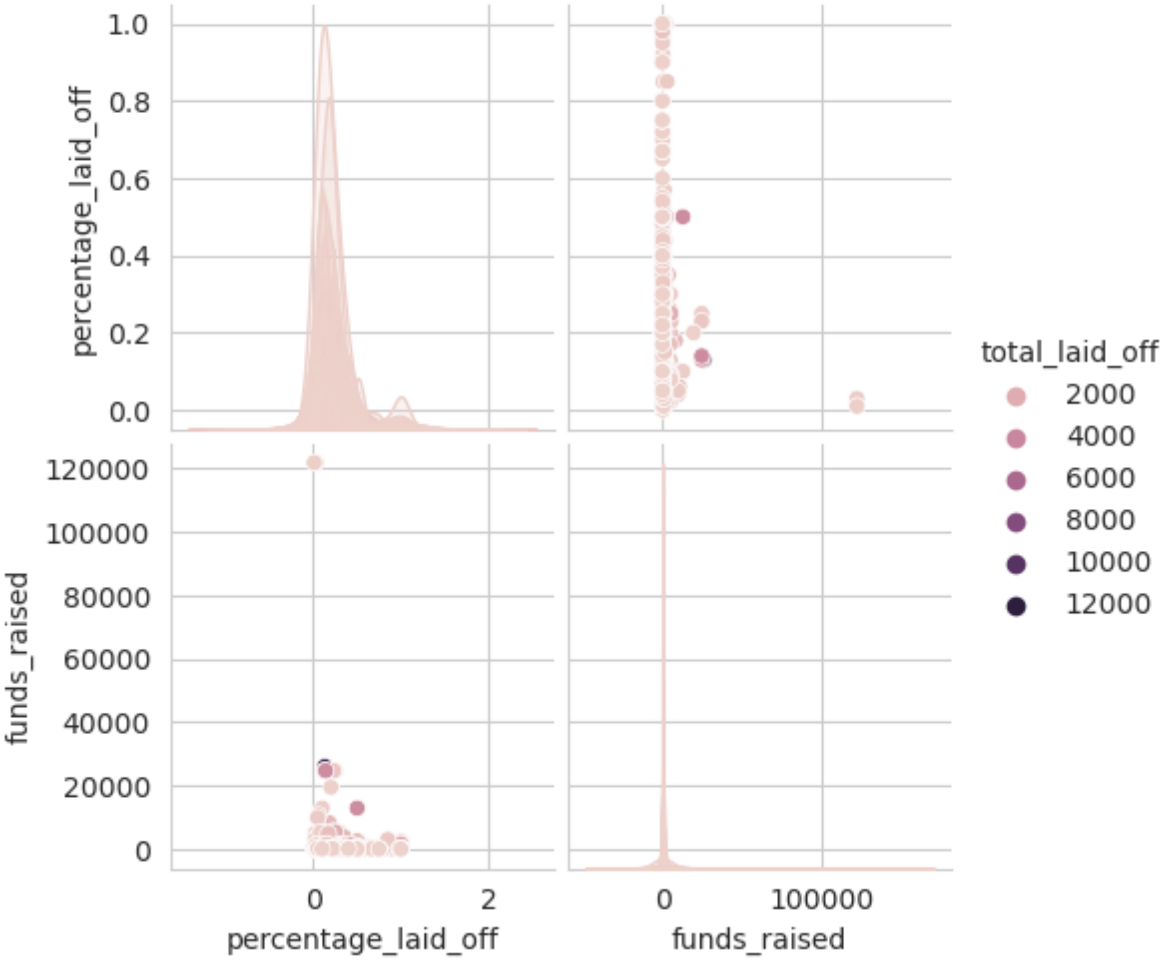


Task 3: Decision Tree

In [226…

```
# Author: Shreya Saha
from sklearn.tree import DecisionTreeClassifier # Import Decision Tree Class
from sklearn import metrics #Import scikit-learn metrics module for accuracy

## This sets the plot style
## to have a grid on a white background
sns.set_style("whitegrid")

print(df.head())

sns.pairplot(data=data, hue='total_laid_off')
plt.show()
```

```
      company       location        industry  total_laid_off  \
0         N26         Berlin         Finance            71.0
2     Dropbox    SF Bay Area           Other           500.0
3       Vroom  New York City  Transportation           120.0
4  Greenhouse  New York City      Recruiting           100.0
7    Megaport       Brisbane  Infrastructure            50.0

   percentage_laid_off        date           stage        country  \
0                 0.04  2023-04-28        Series E  United States
2                 0.16  2023-04-27        Post-IPO  United States
3                 0.11  2023-04-27        Post-IPO  United States
4                 0.12  2023-04-27  Private Equity  United States
7                 0.16  2023-04-27        Post-IPO      Australia

   funds_raised  year
0        1700.0  2023
2        1700.0  2023
3        1300.0  2023
4         110.0  2023
7          98.0  2023
```



In [227…

```
#split dataset in features and target variable
feature_cols = ['funds_raised']
X = df[feature_cols] # Features
y = df.total_laid_off # Target variable
```

In [228…

```
# Split dataset into training set and test set
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, ran
```

In [229…

```
# Create Decision Tree classifer object
clf = DecisionTreeClassifier()

# Train Decision Tree Classifer
clf = clf.fit(X_train,y_train)

#Predict the response for test dataset
y_pred = clf.predict(X_test)
# Model Accuracy, how often is the classifier correct?
print("Accuracy:",metrics.accuracy_score(y_test, y_pred))
```

```
Accuracy: 0.030042918454935622
```

In [230…

```
# Create Decision Tree classifer object
clf = DecisionTreeClassifier(criterion="entropy", max_depth=3)

# Train Decision Tree Classifer
clf = clf.fit(X_train,y_train)

#Predict the response for test dataset
y_pred = clf.predict(X_test)

# Model Accuracy, how often is the classifier correct?
print("Accuracy:",metrics.accuracy_score(y_test, y_pred))
```

```
Accuracy: 0.07296137339055794
```

The decision tree here only uses one feature, but it requires more characterization of mass layoff data and needs more work for an appropriate decision tree model. So, we expect the accuracy can be improved.

Future work

We plan to compare directly with the other measurements. Then, we can build a similar predictive model to compare accuracy.

- COVID data
- stock market
- GDP
- Demographics
- Percent of workspace change (e.g., remote / hybrid / on-site)
- Funds raised
- Effects of Artificial Intelligence, voluntary retirement and mental health

Lastly, we would like to put them into a platform that allows a employer to track their company's health as a mass layoff event would not help the growth of a company.

Question 1: How does a global mass layoff vary from country to country? For example, GDP vs mass layoffs. How did the economy and company respond to the events (e.g., COVID, workspace change, stock market, tech expansion or global economy slowdown)?

Question 2: How does a user-friendly platform for predicting a mass layoff of a company help employees and employers?

Question 3: Would we see a swarm of mass layoffs clusters at some specific time window or correlates with some events?

Hopefully, you enjoy the jupyter notebook and let's fight for MASS LAYOFFs!! :)