1 Data Source and Collection

*The vulnerable dataset vs non-vulnerable dataset used in Section 3 is 10000:10000.

1.1 Vulnerable

The vulnerable dataset has two main resources:

- From previous research provided. (***The results in Section 3 are from this dataset**)
- Newly fetched NVD data with 400+ more official data than the previous one. (***The *CVE SEVERITY* correlation analysis results in huge difference with new dataset than origin one**.)

*In the provided one, the origin research skipped/ignored some commits from security advisory or blob markdown.

1.2 Non-vulnerable

The non-vulnerable dataset comes from latest Pytorch/Tensorflow GitHub repository. The latest version is considered to be non-vulnerable at this moment (***Need to be confirmed**)

2 Metric Process

Transfer the raw dataset/source to a metric-processed one with details.

2.1 Metric Definition

Metrics	**Description**	**Details**
Basic		
URL	The URL link source	GitHub commit/pull request
Repo Name	The Repository name	GitHub repository name
Date	The time of the URL commit	The time that a vulnerability was solved
CVE ID	The CVE id	Official CVE ID from NVD
CVE Severity	The CVE severity	The latest CVE severity metric's base score
Name	Component name	The component is the base unit
Component Type	Component type	File or Group. Group definition is based on the locality within the same CVE issues/commit
Code ownership		
Ownership	The ownership	The highest ownership of a component
Num of Contributor	The sum of contributors	The sum of the contributors to a component
Num of Minor T%	The amount of the minor contributors	The total amount of the minor contributors to a component. Contributor with ownership under T% is Minor contributor. (* T%: 5%, 10%, 20%, 50%)
Per of Minor T%	The proportion of the minor contributors	The proportion of the minor contributors over all the contributor amount

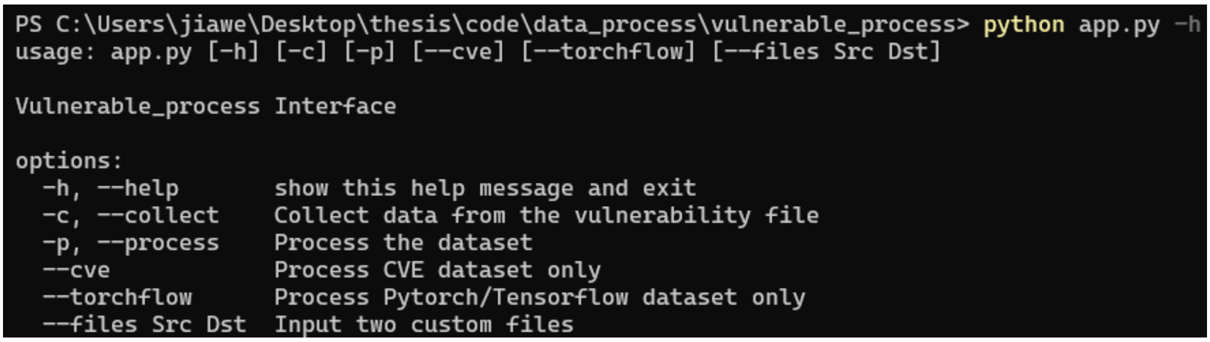
Avg of Minor Contri T%	The average of minor contributor's ownership	The average value of the minor contributors' ownership
Time/Release (See 2.2 for details)		
Days Difference	The project existing time	The existing time of the project in GitHub repository till the **Date**
Age	The component lifetime	The component lifetime calculated based on Git Log info
Time Stage Numeric	Five Time stages	The five Time stages' numerical value. Calculated by **Days Difference**
Time Stage Aged Numeric	Five Time stages Aged	The five Time stages' numerical value. Calculated by **Age**
Oss Stage Numeric	Six Oss stages	The six Oss stages' numerical value. Calculated by **Days Difference**
Oss Stage Aged Numeric	Six Oss stages Aged	The six Oss stages' numerical value. Calculated by **Age**
Classic metrics		
Code churn	NLOC	The number of lines changed = total added + total deleted
File Size	File Size	The number of lines for a component
Churn rate	Churn rate	= Code churn / File Size

2.2 Time Stage + Oss Stage Metric

Metric	**Details**	**Numeric Value**
Time Stage		
T1	The given time period is in 0 to 7 days	1
T2	The given time period is in 7 days to 3 months	2
T3	The given time period is in 3 months to 9 months	3
T4	The given time period is in 2 years to 3 years	4
T5	The given time period is beyond 3 years	5
Oss Stage		
SI	Success Initialisation. Has at least one successful release	1
TI	Tragedy Initialisation. Within the given time period (>1year), no release	2
SG	Success Growth. >= 3 releases AND >= 6 months between releases	5
TG	Tragedy Growth. 1 or 2 releases and >=1 year since the last release at the time of data collection	6
II	Indeterminate Initialisation. 0 releases and < 1 year since project registration	3
IG	Indeterminate Growth. 1 or 2 releases and < 1 year since the last release OR 3 releases and < 6 months between releases	4

2.3 Vulnerable process + App interface

An application interface (vulnerable process) is created for processing the raw dataset to distilled one under the metric defined. This application interface defaults to calculate the provided dataset from Section 1. And it enables user to calculate the metric info with given commit/pull request URLs (CVE ID optional).



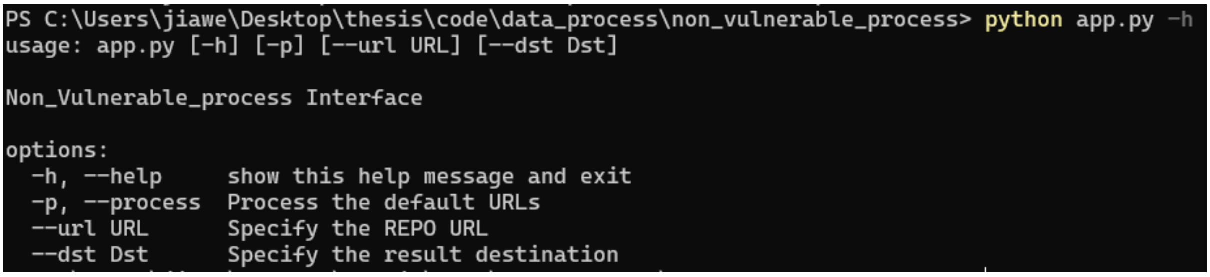
```
PS C:\Users\jiawe\Desktop\thesis\code\data_process\vulnerable_process> python app.py -h
usage: app.py [-h] [-c] [-p] [--cve] [--torchflow] [--files Src Dst]

Vulnerable_process Interface

options:
  -h, --help        show this help message and exit
  -c, --collect     Collect data from the vulnerability file
  -p, --process     Process the dataset
  --cve             Process CVE dataset only
  --torchflow       Process Pytorch/Tensorflow dataset only
  --files Src Dst   Input two custom files
```

2.4 Non-vulnerable process + App interface

An application interface (non-vulnerable process) is created for calculate the metric info of a Git repository. The application interface defaults to process the local Git repo specified in settings, while also allows user to examine the repo with an external GitHub repo URL.



```
PS C:\Users\jiawe\Desktop\thesis\code\data_process\non_vulnerable_process> python app.py -h
usage: app.py [-h] [-p] [--url URL] [--dst Dst]

Non_Vulnerable_process Interface

options:
  -h, --help     show this help message and exit
  -p, --process  Process the default URLs
  --url URL      Specify the REPO URL
  --dst Dst      Specify the result destination
```

3 Result Analysis

3.1 Exploring Nature of Data

In summary, the dataset is not normally distributed.

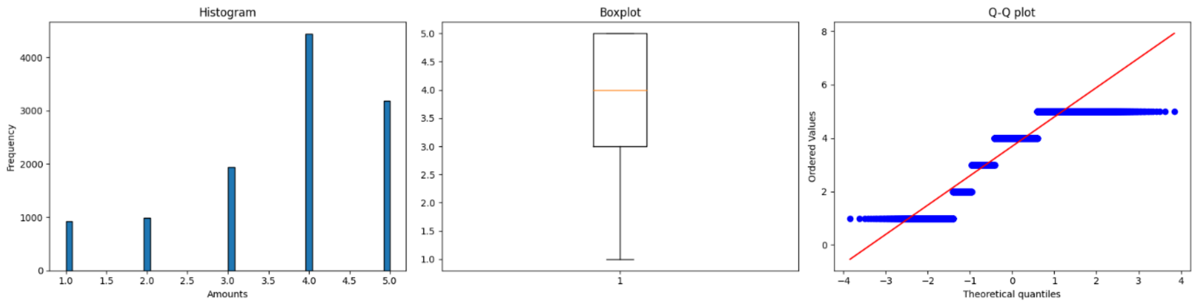
3.1.1 Descriptive statistics

Metrics	**N**	**Min**	**Max**	**Mean**		**Std. Dev.**
				Statistics	***Std. Error***	
CVE Severity	658	3.3	9.9	6.465502	0.05183	1.329519
Ownership	11491	0.044088	1.00000	0.443906	0.0023718	0.254253
Num of Minor 10%	11491	0.0	364	11.495779	0.212516	22.780893
Per of Minor 10%	11491	0.000000	1.000000	0.499368	0.003641055	0.390307
Avg of Minor Contri 10%	11491	0.000000	0.100000	0.030714	0.0002789549	0.029903
Days Difference	11491	58	3962	1634.073275	5.91280283	633.829298

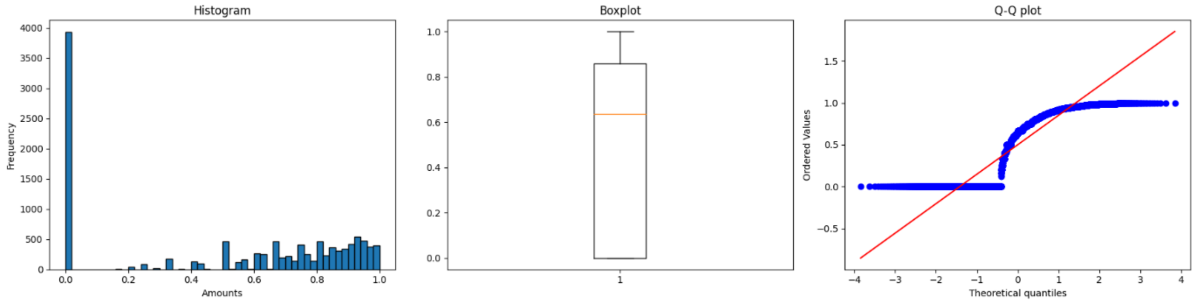
Age	11491	0.000000	2548	745.52884	6.4916690	695.881488
Time Stage Aged Numeric	11491	1.000000	5.000000	3.693325	0.011131	1.193224
Oss Stage Aged Numeric	11491	1.000000	6.000000	1.49195	0.01117426	1.197837
File Size	11491	0.000000	48295	621.776956	12.434681455	1332.949133
Code churn	11491	0.00000	8.137754e+06	2.659028e+03	709.30357	7.603456e+04
Churn rate	11491	0.000000	43785.714286	310.596780	12.22779542	1310.771761

3.1.2 Histogram, box plot, normal Q-Q plot

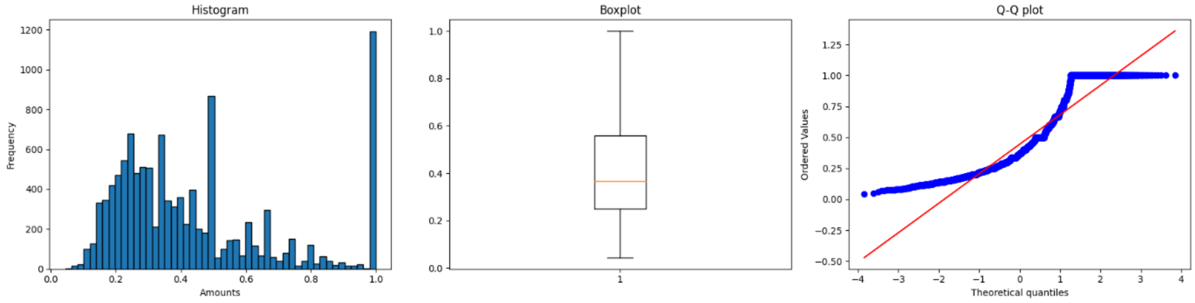
Diagrams Time Stage Aged Numeric



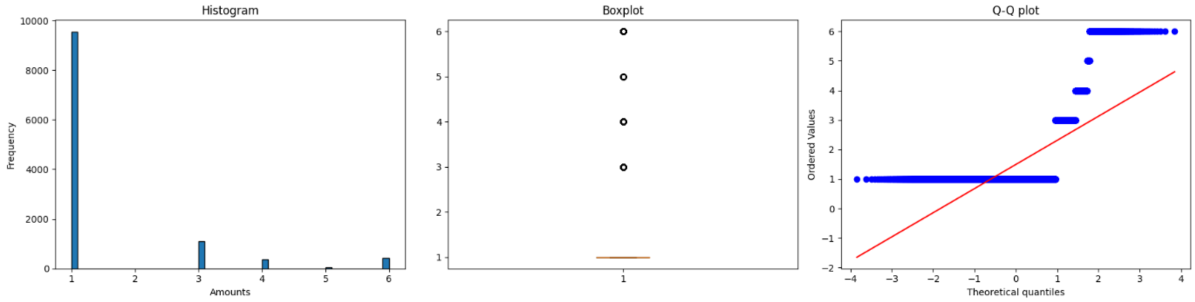
Diagrams Per of Minor 10%



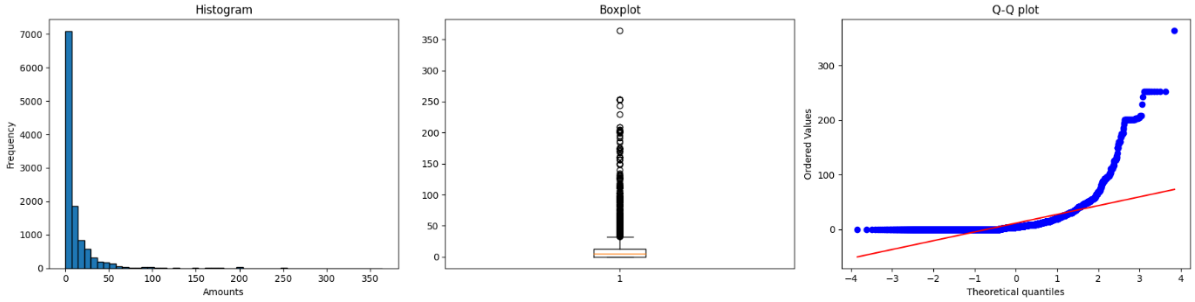
Diagrams Ownership



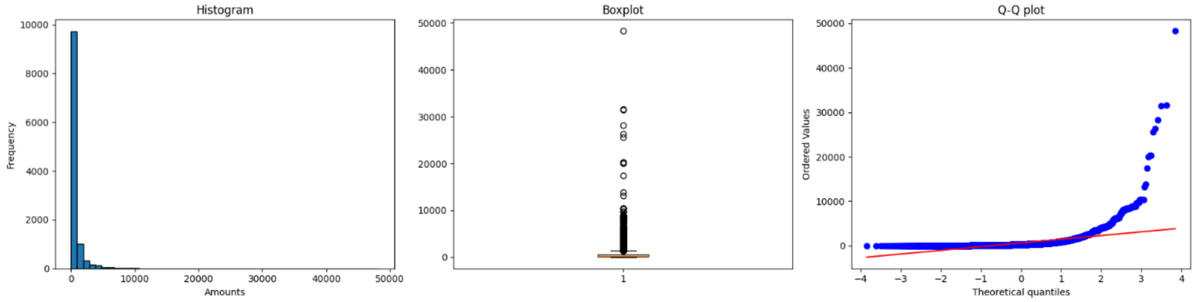
Diagrams Oss Stage Aged Numeric



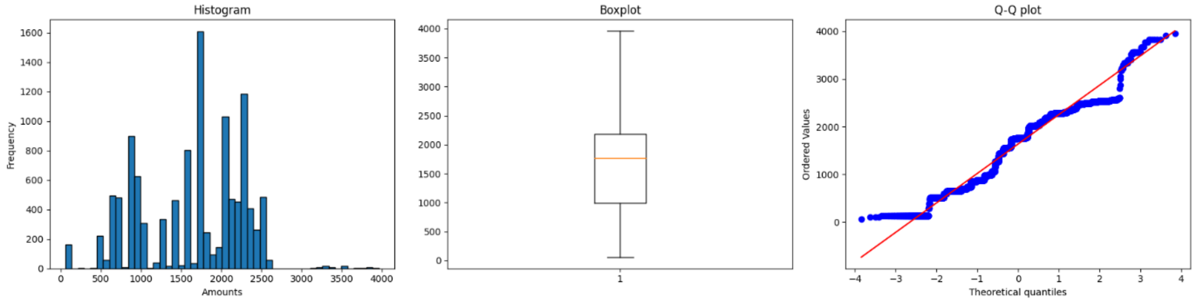
Diagrams Num of Minor 10%



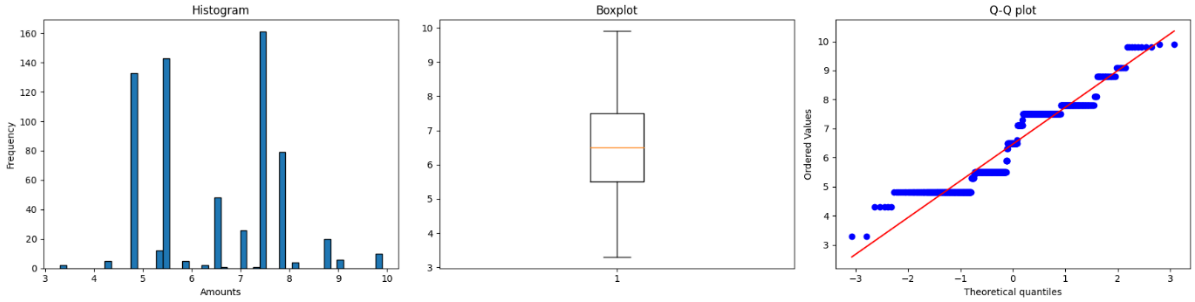
Diagrams File Size

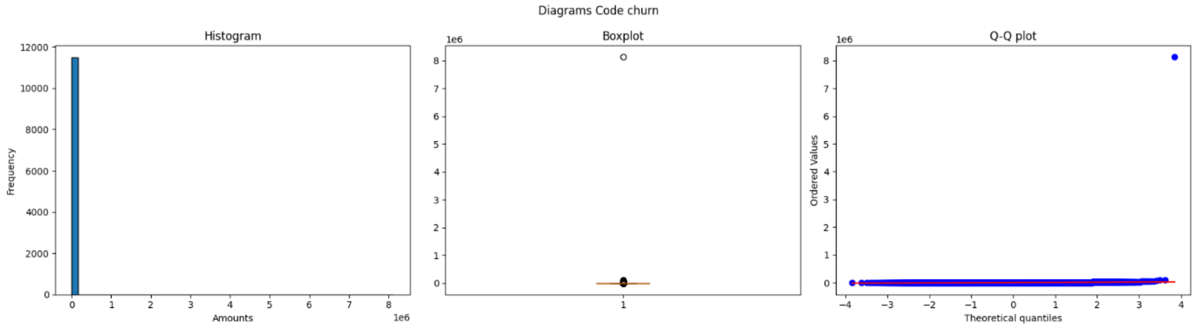


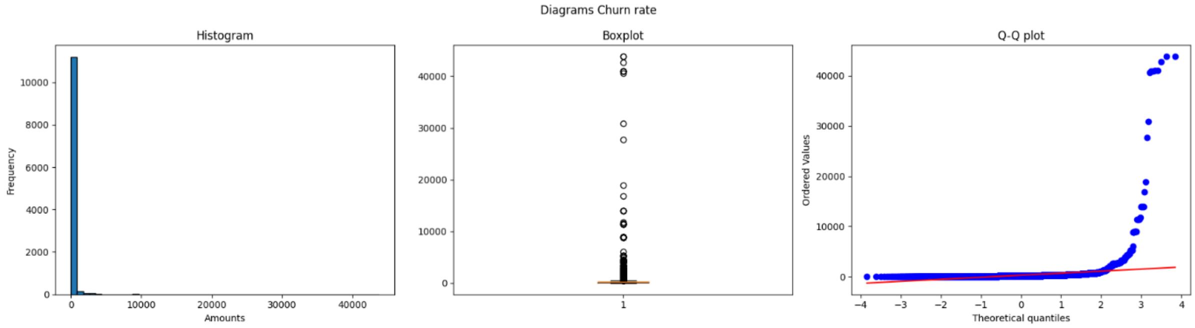
Diagrams Days Difference

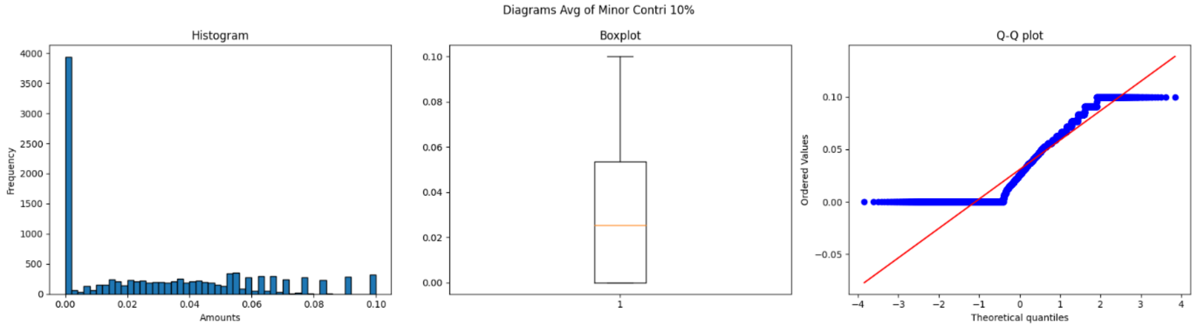


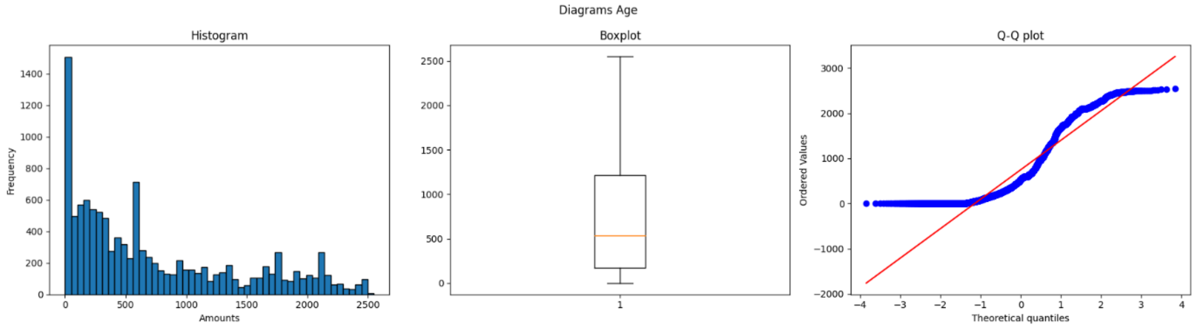
Diagrams CVE Severity











3.1.3 Skewness and Kurtosis check

Metrics	**Skewness**			**Kurtosis**		
	Statistics	***Std. Error***	***z-value***	***Statistics***	***Std. Error***	***z-value***
CVE Severity	0.1659	0.0955	1.7373	-1.0004	0.1910	-5.2382
Ownership	0.9957	0.0229	43.5761	-0.0209	0.0457	-0.4567
Num of Minor 10%	5.3191	0.0229	232.7788	40.1170	0.0457	877.8117
Per of Minor 10%	-0.2888	0.0229	-12.6392	-1.6201	0.0457	-35.4499
Avg of Minor Contri 10%	0.5876	0.0229	25.7146	-0.7820	0.0457	-17.1108

Days Difference	-0.2815	0.0229	-12.3203	-0.6759	0.0457	-14.7900
Age	0.8587	0.0229	37.5774	-0.4880	0.0457	-10.6781
Time Stage Aged Numeric	-0.8369	0.0229	-36.6245	-0.1359	0.0457	-2.9747
Oss Stage Aged Numeric	2.5320	0.0229	110.8056	5.7030	0.0457	124.7880
File Size	11.2856	0.0229	493.8879	253.9972	0.0457	5557.7908
Code churn	106.6004	0.0229	4665.1112	11402.7559	0.0457	249507.2201
Churn rate	25.5640	0.0229	1118.7464	758.3895	0.0457	16594.5545

3.1.4 Shaprio-Wilk and Kologorow-Smirnow tests

Metrics	**Shaprio-Wilk**		**Kolmogorov-Smirnov**	
	Statistics	***Sig.***	***Statistics***	***Sig.***
CVE Severity	0.8971	0.0000	0.9995	0.0000
Ownership	0.8746	0.0000	0.5380	0.0000
Num of Minor 10%	0.4976	0.0000	0.6089	0.0000
Per of Minor 10%	0.8113	0.0000	0.5000	0.0000
Avg of Minor Contri 10%	0.8807	0.0000	0.5000	0.0000
Days Difference	0.9497	0.0000	1.0000	0.0000
Age	0.8764	0.0000	0.9237	0.0000
Time Stage Aged Numeric	0.8495	0.0000	0.8966	0.0000
Oss Stage Aged Numeric	0.4640	0.0000	0.8413	0.0000
File Size	0.3893	0.0000	0.9453	0.0000
Code churn	0.0059	0.0000	0.9458	0.0000
Churn rate	0.0965	0.0000	0.8977	0.0000

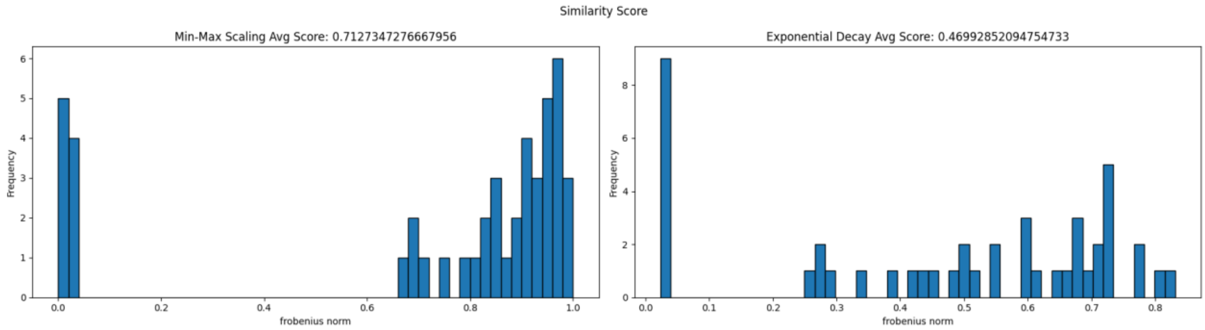
3.2 Possible Distortion Check

In summary, vulnerability proportion/threshold/locality does not have significant influence on correlation heatmap.

3.2.1 Proportion influence

Sample the vulnerable dataset as 10% - 100% to the non-vulnerable dataset.

Frobenius Norm of Matrix Differences										
	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
10%		0.4925	0.6945	4.018	0.9668	1.1172	1.1963	1.2680	1.2731	1.4400
20%			0.4184	3.92628	0.5968	0.8514	0.8653	0.9323	0.9202	1.1338
30%				3.9246	0.4991	0.5551	0.7219	0.6567	0.7922	0.8971
40%					3.9006	3.9386	3.918	3.9287	3.9318	3.9357
50%						0.5065	0.4408	0.5102	0.4017	0.7171
60%							0.4028	0.3812	0.5271	0.4660
70%								0.4939	0.3026	0.4382
80%									0.4273	0.4149
90%										0.4637
100%										



Mantel Test										
	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
10%		0.9326	0.9943	0.9885	0.9858	0.9827	0.9790	0.9752	0.9759	0.9736
20%			0.9326	0.9316	0.9300	0.9303	0.9294	0.9323	0.9297	0.9258
30%				0.9968	0.9949	0.9931	0.9905	0.9871	0.9886	0.9864
40%					0.9973	0.9974	0.9963	0.9927	0.9935	0.9919
50%						0.9977	0.9965	0.9959	0.9953	0.9953
60%							0.9971	0.9980	0.9968	0.9977
70%								0.9986	0.9974	0.9978
80%									0.9977	0.9988
90%										0.9993
100%										

3.2.2 Threshold influence

Check the similarity score between each threshold.

Threshold vs Is_Defective												
	5%			10%			20%			50%		
	Cosine Similarity	K-S Statistics		Cosine Similarity	K-S Statistics		Cosine Similarity	K-S Statistics		Cosine Similarity	K-S Statistics	
		Statistic	P-value		Statistic	P-value		Statistic	P-value		Statistic	P-value
5%				0.9196	0.0769	0.9765	0.7955	0.1282	0.5459	0.5715	0.1538	0.3159
10%							0.9237	0.1025	0.8099	0.6818	0.1538	0.3159
20%										0.8233	0.1282	0.5459
50%												

Threshold vs Vulnerable												
	5%			10%			20%			50%		
	Cosine Similarity	K-S Statistics		Cosine Similarity	K-S Statistics		Cosine Similarity	K-S Statistics		Cosine Similarity	K-S Statistics	
		Statistic	P-value		Statistic	P-value		Statistic	P-value		Statistic	P-value
5%				0.9100	0.1282	0.5459	0.7651	0.1666	0.2296	0.5792	0.2179	0.0489
10%							0.9136	0.1025	0.8099	0.7248	0.1410	0.4221
20%										0.8851	0.1025	0.8099
50%												

Threshold vs CVE Severity												
	5%			10%			20%			50%		
	Cosine Similarity	K-S Statistics		Cosine Similarity	K-S Statistics		Cosine Similarity	K-S Statistics		Cosine Similarity	K-S Statistics	
		Statistic	P-value		Statistic	P-value		Statistic	P-value		Statistic	P-value
5%				0.8872	0.1282	0.5459	0.7028	0.1538	0.3159	0.5393	0.1794	0.1624
10%							0.8906	0.1282	0.5459	0.7166	0.1666	0.2296
20%										0.9090	0.1025	0.8099
50%												

3.2.3 Locality Clustering influence

Check the similarity between heatmap generated by file component and group component.

Mantel Test		
	Group Component	
	Correlation	P-value
File Component	0.8219009665635432	0.001

3.3 Correlation Check

In summary:

- Check if is defective: Days Difference, Age
- Time Stage Aged Numeric: Per of Minor 10%, Oss Stage Aged Numeric
- CVE Severity: Days Difference

Between each metric, it seems like they are independent/robust with each other.

3.3.1 Correlation

Correlation									
	Is Defective			***Time Stage Aged Numeric***			***CVE Severity***		
	Pearson	Spearman	Kendall	Pearson	Spearman	Kendall	Pearson	Spearman	Kendall
Ownership	-0.12	-0.10	-0.08	-0.73	-0.62	-0.50	-0.03	-0.07	-0.05
Num of contributor	0.16	0.22	0.19	0.38	0.70	0.58	0.11	0.08	0.06
Num of Minor 10%	0.16	0.23	0.20	0.36	0.64	0.53	0.12	0.09	0.06
Per of Minor 10%	0.23	0.23	0.20	0.64	0.63	0.52	0.06	0.07	0.05
Avg of Minor Contri 10%	0.13	0.17	0.15	0.36	0.38	0.29	-0.01	0.01	0.01
Days Difference	-0.81	-0.92	-0.82	0.22	0.32	0.25	0.45	0.44	0.35
Age	-0.61	-0.60	-0.49	0.81	0.96	0.86	0.25	0.26	0.19
Oss Stage Aged Numeric	0.25	0.28	0.27	-0.58	-0.59	-0.51	-0.02	-0.02	-0.02
File Size	0.14	0.40	0.33	0.17	0.25	0.19	0.10	0.16	0.12
Code churn	0.01	0.36	0.30	0.02	0.49	0.38	0.12	0.14	0.10
Churn rate	-0.01	-0.00	-0.00	0.09	0.45	0.36	0.06	0.01	0.01

3.3.2 Robustness

Robustness (Multiple Linear Regression)						
	R-squared	Adj. R2	F-statistic	Coefficient	Std err	P-value
Is Defective						
Days Difference	0.659	0.659	4.582e+04	-0.0005	2.51e-06	0.000
Days Difference (Controlled by Classic)	0.665	0.665	1.572e+04	-0.0005	2.5e-06	0.000

Age	0.367	0.367	1.373e+04	-0.0003	2.77e-06	0.000
Age (Controlled by Classic)	0.388	0.388	5020.	-0.0003	2.72e-06	0.000
Time Stage Aged Numeric						
Num of Minor 10%	0.131	0.131	1734.	0.0190	0.000	0.000
Per of Minor 10%	0.413	0.413	8099.	1.9658	0.022	0.000
Per of Minor 10% (Controlled by Classic)	0.416	0.415	2723.	2.0164	0.023	0.000
Oss Stage Aged Numeric	0.332	0.332	5715.	-0.5741	0.008	0.000
Oss Stage Aged Numeric (Controlled by Classic)	0.347	0.347	2033.	-0.5628	0.008	0.000
Per of Minor 10% + Oss Stage Aged Numeric	0.553	0.552	7093.	1.5344 + -0.3972	0.020 + 0.007	0.000
CVE Severity						
Days Difference	0.202	0.201	222.7	0.0021	0.000	0.000
Days Difference (Controlled by Classic)	0.203	0.200	74.64	0.0020	0.000	0.000
Age	0.060	0.059	56.50	0.0005	6.06e-05	0.000
Days Difference (Controlled by Minor)	0.202	0.200	111.4	0.0020	0.000	0.002

4 Problems and Further

4.1 Problems

- With the newly fetch data from NVD, when I move to the correlation analysis between metrics and CVE Severity, it shows that there is no correlation between CVE Severity and any metric, which is significant different from the results from origin dataset. While, only 400+ entries are updated in the new dataset (1200+ in total).
- The definition of the OSS Stage metric. I just randomly assign the stage with numeric value, but it seems like there are some correlations.
- Non-vulnerable dataset source and definition.
- Is there any point of the metric needed to be re-defined/added? Like adding `Major` attribute.

4.2 Further

- Prediction?
- The reasons that affect or cause minor?
- Correlation between metrics? (Paper: Effects of measurements on correlations of software code metrics)