CWE_Analysis

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1 Group 9

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3 DSE 203 Final Project - Common Vulnerability and Exposure Analysis

[78]:
```
import os
import json
from neo4j import GraphDatabase
import codecs
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
sns.set_theme(style="whitegrid")
```

4 Connecting to Neo4j API

[79]:
```
uri = "neo4j://localhost:7687"
userName = "neo4j"
password = "password"
```

[80]:
```
# Connect to the neo4j database server
graph_db_driver  = GraphDatabase.driver(uri, auth=(userName, password))
```

[81]:
```
base_dir = '/Users/janamian/Documents/workstation/ucsd_dse_program/fall_2019/
 ↪docker_vol/saba-ja/workstation/dse_203_2020/project/
 ↪dse_203_final_project_fall_2020/data'
```

[82]:
```
with open(os.path.join(base_dir, 'cwe_data', 'cwec_v4.2.json')) as f:
    cwe = json.load(f)

# with open(os.path.join(base_dir, 'nvd_data', 'nvdcve-1.1-2020.json')) as f:
#     nvd = json.load(f)
```

5 Count types

[83]:
```
cwe_type_counter = {}
for obj in cwe['Weakness_Catalog']['Weaknesses']['Weakness']:
    for key, val in obj.items():
        t = cwe_type_counter.get(key, 0)
        if t == 0:
            cwe_type_counter[key] = 1
        else:
            cwe_type_counter[key] = cwe_type_counter[key] + 1
```

[84]:
```
cwe_type_counter
```

[84]:
```
{'@ID': 914,
 '@Name': 914,
 '@Abstraction': 914,
 '@Structure': 914,
 '@Status': 914,
 'Description': 914,
 'Extended_Description': 650,
 'Related_Weaknesses': 882,
 'Applicable_Platforms': 666,
 'Background_Details': 44,
 'Modes_Of_Introduction': 776,
 'Likelihood_Of_Exploit': 187,
 'Common_Consequences': 870,
 'Potential_Mitigations': 614,
 'Demonstrative_Examples': 475,
 'Observed_Examples': 392,
 'References': 496,
 'Content_History': 914,
 'Weakness_Ordinalities': 256,
 'Alternate_Terms': 83,
 'Detection_Methods': 89,
 'Taxonomy_Mappings': 628,
 'Related_Attack_Patterns': 273,
 'Notes': 313,
 'Affected_Resources': 51,
 'Functional_Areas': 24}
```

[85]:
```
data = {'attribute_element':[], 'count':[]}
for key, value in cwe_type_counter.items():
#     if '@' not in key:
    data['attribute_element'].append(key)
    data['count'].append(value)

cwe_type_df = pd.DataFrame(data)
```

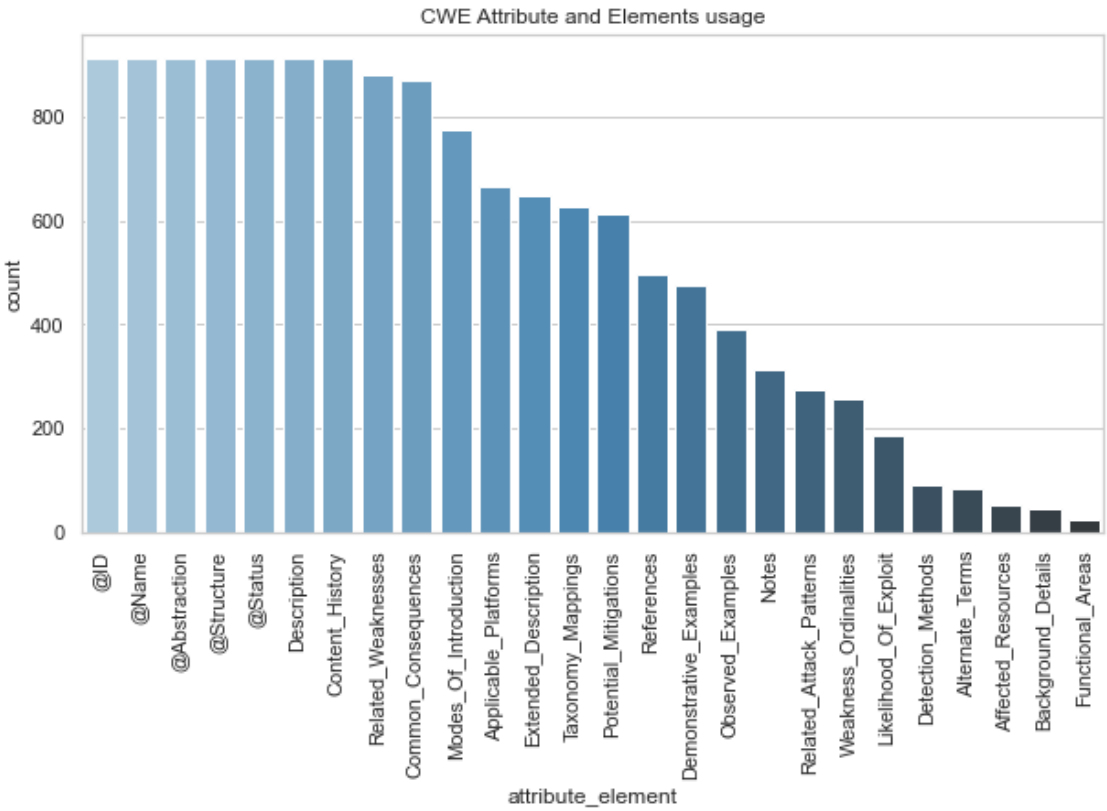
```
cwe_type_df.sort_values(by=['count'], ascending=False, inplace=True)
cwe_type_df.reset_index(drop=True, inplace=True)
```

[86]:
```
cwe_type_df
```

[86]:

	attribute_element	count
0	@ID	914
1	@Name	914
2	@Abstraction	914
3	@Structure	914
4	@Status	914
5	Description	914
6	Content_History	914
7	Related_Weaknesses	882
8	Common_Consequences	870
9	Modes_Of_Introduction	776
10	Applicable_Platforms	666
11	Extended_Description	650
12	Taxonomy_Mappings	628
13	Potential_Mitigations	614
14	References	496
15	Demonstrative_Examples	475
16	Observed_Examples	392
17	Notes	313
18	Related_Attack_Patterns	273
19	Weakness_Ordinalities	256
20	Likelihood_Of_Exploit	187
21	Detection_Methods	89
22	Alternate_Terms	83
23	Affected_Resources	51
24	Background_Details	44
25	Functional_Areas	24

[87]:
```
plt.figure(figsize=(10,5))
ax = sns.barplot(x="attribute_element", y="count", palette="Blues_d",␣
↪data=cwe_type_df);
plt.title('CWE Attribute and Elements usage')
plt.setp(ax.get_xticklabels(), rotation=90);
```



[88]:
```
def run_query(q):
    with graph_db_driver.session() as graph_db_session:
        try:
            graph_db_session.run(q)
        except:
            print(q)
            raise NameError
```

[89]:
```
def get_cwe_name_by_id(cwe_id_val):
    for obj in cwe['Weakness_Catalog']['Weaknesses']['Weakness']:
        cwe_id = obj['@ID']
        if int(cwe_id) == int(cwe_id_val):
            return obj['@Name']
```

6 Create CWE nodes and properties

[90]:
```
# ####################
# Create CWE nodes and properties
# ####################
delete_query = 'MATCH (n) DETACH DELETE n'
```

```
run_query(delete_query)
for obj in cwe['Weakness_Catalog']['Weaknesses']['Weakness']:
    cwe_id = obj['@ID']
    name = obj['@Name'].replace('\\','\\\\').replace('"', '\\"').replace("'",␣
 ↪"\\'")
    desc = obj['Description'].replace('\\','\\\\').replace('"', '\\"').
 ↪replace("'", "\\'")
    likelihood_of_exploit = obj.get('Likelihood_Of_Exploit', 'Unknown')
    if likelihood_of_exploit == "Unknown":
        community = 0
    elif likelihood_of_exploit == "Low":
        community = 1
    elif likelihood_of_exploit == "Medium":
        community = 2
    elif likelihood_of_exploit == "High":
        community = 3
    else:
        print(cwe_id, likelihood_of_exploit)

    cql_create_cwe_node = f"""CREATE (:cwe {{ cwe_id: "{cwe_id}",
    name: "{name}",
    description: "{desc}",
    community: {community},
    likelihood_of_exploit: "{likelihood_of_exploit}"
    }})"""
    run_query(cql_create_cwe_node)
```

[91]:
```
cql_create_cwe_node = f"""CREATE (:cwe {{ cwe_id: "NVD-CWE-Other",
    name: "Other",
    description: "NVD is only using a subset of CWE for mapping instead of the␣
 ↪entire CWE, and the weakness type is not covered by that subset.",
    community: 0,
    likelihood_of_exploit: "Unknown"
    }})"""
run_query(cql_create_cwe_node)
```

[92]:
```
cql_create_cwe_node = f"""CREATE (:cwe {{ cwe_id: "NVD-CWE-noinfo",
    name: "Insufficient Information",
    description: "There is insufficient information about the issue to classify␣
 ↪it; details are unkown or unspecified.",
    community: 0,
    likelihood_of_exploit: "Unknown"
    }})"""
run_query(cql_create_cwe_node)
```

[93]:
```
cql_create_cwe_node = f"""CREATE (:cwe {{ cwe_id: "NVD-no-analysis",
    name: "No Analysis",
    description: "CVEs mapping to this CWE are either rejected or do not have␣
 ↪any mapping to any CWE",
    community: 0,
    likelihood_of_exploit: "Unknown"
    }})"""
run_query(cql_create_cwe_node)
```

7 Create CWE weakness relationship

[94]:
```
# ####################
# Create CWE weakness relationship
# ####################
relationship_set = set()
relationship_count = {}
for obj in cwe['Weakness_Catalog']['Weaknesses']['Weakness']:
    cwe_id = obj['@ID']
    name = obj['@Name']
    try:
        rel_obj = obj['Related_Weaknesses']['Related_Weakness']
    except KeyError:
        print(f'{cwe_id} has no outward weakness relationship. Name: {name}')
        continue

    if not isinstance(rel_obj, list):
        rel_obj_list = [rel_obj]
    else:
        rel_obj_list = rel_obj

    for rel in rel_obj_list:
        related_cwe_id = rel['@CWE_ID']
        relationship = rel['@Nature']
        rel_str = f'({cwe_id})->[{relationship}]->({related_cwe_id})'
        if rel_str in relationship_set:
            continue
        else:
            relationship_set.add(rel_str)

        if relationship == 'ChildOf':
            child_count = relationship_count.get(related_cwe_id, 0)
            child_count += 1
            relationship_count[related_cwe_id] = child_count

        cql_create_relationship = f"""MATCH (cwe1:cwe),(cwe2:cwe)
```

```
                                    WHERE cwe1.cwe_id = '{cwe_id}' AND cwe2.
↪cwe_id = '{related_cwe_id}'
                                    CREATE (cwe1)-[r:{relationship}]->(cwe2)
                                    RETURN type(r)"""
        run_query(cql_create_relationship)

for key, val in relationship_count.items():
    cql_update_cwe_node = f"""MATCH (c:cwe {{ cwe_id: "{key}"}}) SET c.
↪child_count = {val}"""
    run_query(cql_update_cwe_node)
```

```
1187 has no outward weakness relationship. Name: DEPRECATED: Use of
Uninitialized Resource
132 has no outward weakness relationship. Name: DEPRECATED (Duplicate):
Miscalculated Null Termination
216 has no outward weakness relationship. Name: DEPRECATED: Containment Errors
(Container Errors)
217 has no outward weakness relationship. Name: DEPRECATED: Failure to Protect
Stored Data from Modification
218 has no outward weakness relationship. Name: DEPRECATED (Duplicate): Failure
to provide confidentiality for stored data
225 has no outward weakness relationship. Name: DEPRECATED (Duplicate): General
Information Management Problems
247 has no outward weakness relationship. Name: DEPRECATED (Duplicate): Reliance
on DNS Lookups in a Security Decision
249 has no outward weakness relationship. Name: DEPRECATED: Often Misused: Path
Manipulation
284 has no outward weakness relationship. Name: Improper Access Control
292 has no outward weakness relationship. Name: DEPRECATED (Duplicate): Trusting
Self-reported DNS Name
373 has no outward weakness relationship. Name: DEPRECATED: State
Synchronization Error
423 has no outward weakness relationship. Name: DEPRECATED (Duplicate): Proxied
Trusted Channel
435 has no outward weakness relationship. Name: Improper Interaction Between
Multiple Correctly-Behaving Entities
443 has no outward weakness relationship. Name: DEPRECATED (Duplicate): HTTP
response splitting
458 has no outward weakness relationship. Name: DEPRECATED: Incorrect
Initialization
516 has no outward weakness relationship. Name: DEPRECATED (Duplicate): Covert
Timing Channel
533 has no outward weakness relationship. Name: DEPRECATED: Information Exposure
Through Server Log Files
534 has no outward weakness relationship. Name: DEPRECATED: Information Exposure
Through Debug Log Files
542 has no outward weakness relationship. Name: DEPRECATED: Information Exposure
```

```
Through Cleanup Log Files
545 has no outward weakness relationship. Name: DEPRECATED: Use of Dynamic Class
Loading
592 has no outward weakness relationship. Name: DEPRECATED: Authentication
Bypass Issues
596 has no outward weakness relationship. Name: DEPRECATED: Incorrect Semantic
Object Comparison
664 has no outward weakness relationship. Name: Improper Control of a Resource
Through its Lifetime
691 has no outward weakness relationship. Name: Insufficient Control Flow
Management
693 has no outward weakness relationship. Name: Protection Mechanism Failure
697 has no outward weakness relationship. Name: Incorrect Comparison
703 has no outward weakness relationship. Name: Improper Check or Handling of
Exceptional Conditions
707 has no outward weakness relationship. Name: Improper Neutralization
71 has no outward weakness relationship. Name: DEPRECATED: Apple '.DS_Store'
710 has no outward weakness relationship. Name: Improper Adherence to Coding
Standards
769 has no outward weakness relationship. Name: DEPRECATED: Uncontrolled File
Descriptor Consumption
92 has no outward weakness relationship. Name: DEPRECATED: Improper Sanitization
of Custom Special Characters
```

[95]:
```
data = {'parent_id':[], 'parent_name': [], 'child_count':[]}
for key, value in relationship_count.items():
    data['parent_id'].append(key)
    p_name = get_cwe_name_by_id(key).split(' ')[0:6]
    p_name = ' '.join(p_name)
    p_name = f'{p_name} ({key})'
    data['parent_name'].append(p_name)
    data['child_count'].append(value)

cwe_child_count_df = pd.DataFrame(data)
cwe_child_count_df.sort_values(by=['child_count'], ascending=False,␣
↪inplace=True)
cwe_child_count_df.reset_index(drop=True, inplace=True)
cwe_child_count_gt_n = cwe_child_count_df[cwe_child_count_df['child_count'] >=␣
↪20]
cwe_child_count_gt_n2 = cwe_child_count_df[cwe_child_count_df['child_count'] >=␣
↪10]
cwe_child_count_gt_n3 = cwe_child_count_df[cwe_child_count_df['child_count'] >=␣
↪5]
```

[96]:
```
cwe_child_count_df
```

[96]:

	parent_id	parent_name	child_count
0	710	Improper Adherence to Coding Standards (710)	35
1	20	Improper Input Validation (20)	34
2	664	Improper Control of a Resource Through (664)	33
3	284	Improper Access Control (284)	32
4	287	Improper Authentication (287)	27
..	…	…	…
225	1286	Improper Validation of Syntactic Correctness o…	1
226	489	Active Debug Code (489)	1
227	524	Use of Cache Containing Sensitive Information …	1
228	1229	Creation of Emergent Resource (1229)	1
229	96	Improper Neutralization of Directives in Stati…	1

[230 rows x 3 columns]

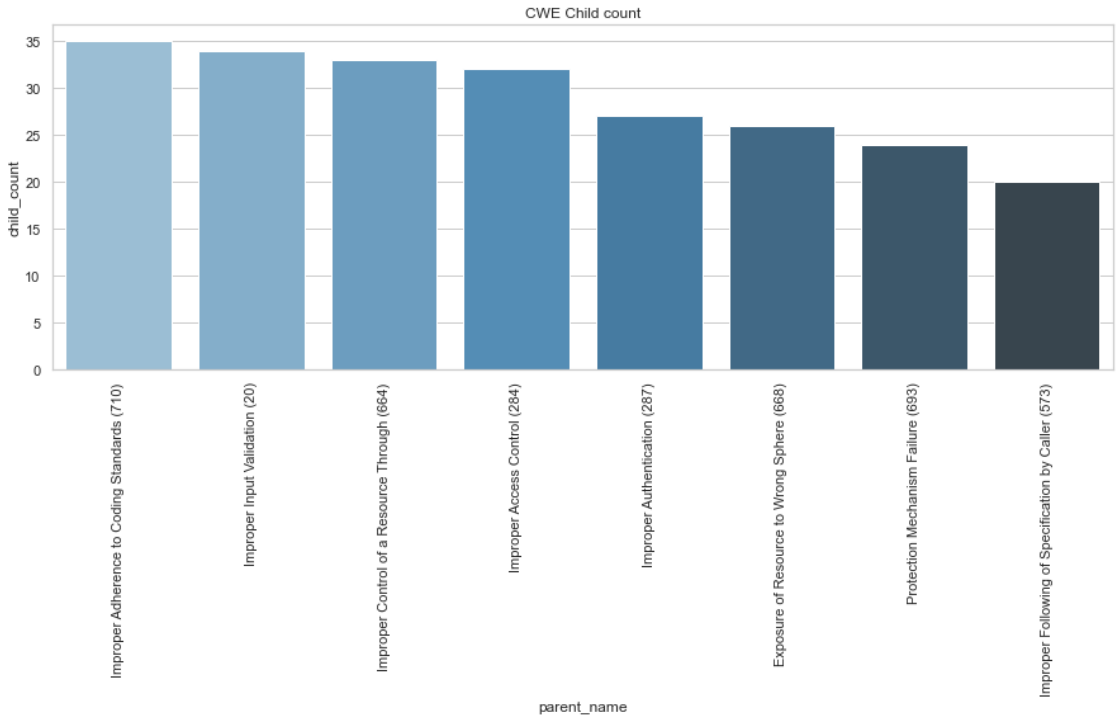
[97]:
```
cwe_child_count_gt_n
```

[97]:

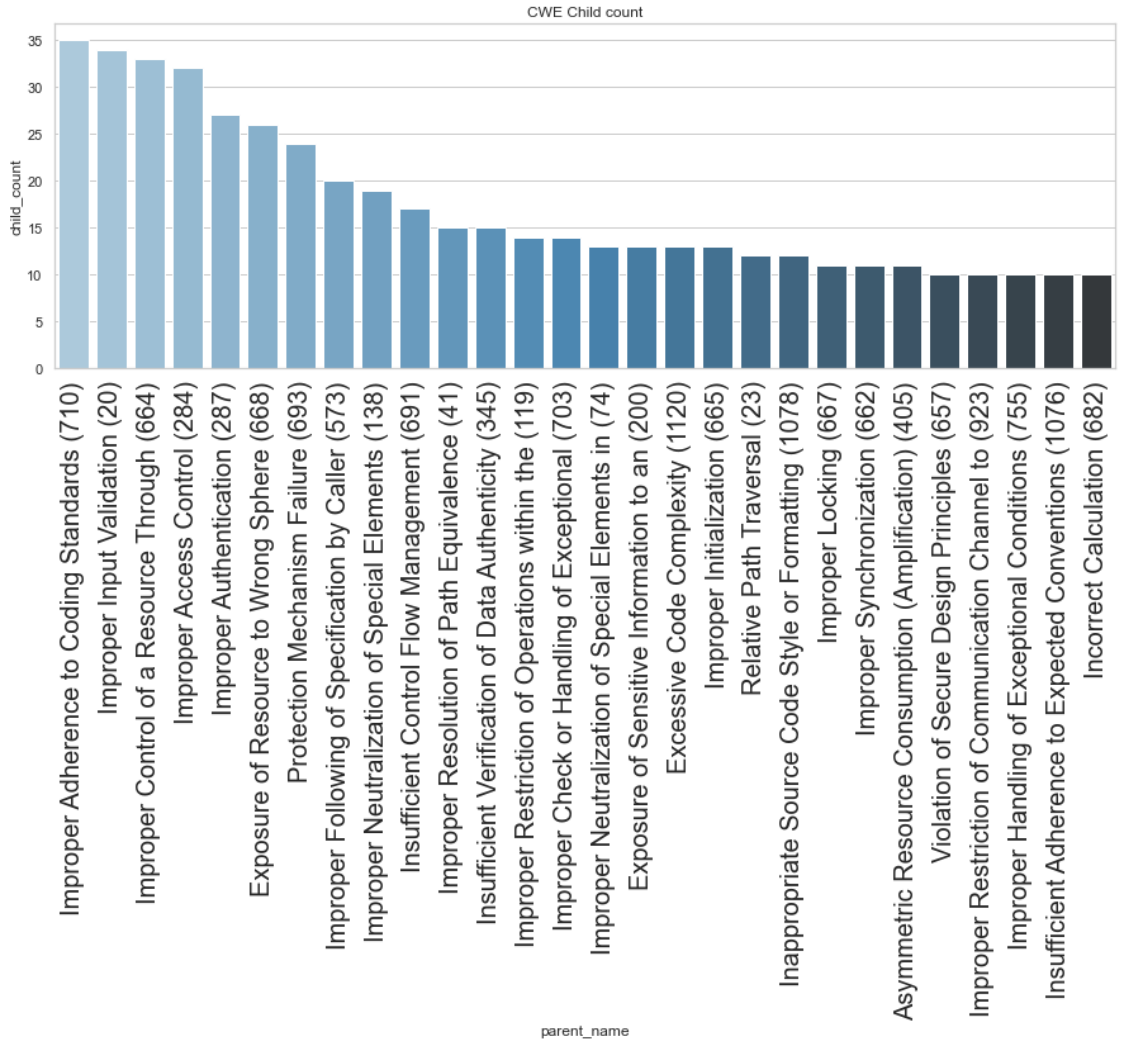
	parent_id	parent_name	child_count
0	710	Improper Adherence to Coding Standards (710)	35
1	20	Improper Input Validation (20)	34
2	664	Improper Control of a Resource Through (664)	33
3	284	Improper Access Control (284)	32
4	287	Improper Authentication (287)	27
5	668	Exposure of Resource to Wrong Sphere (668)	26
6	693	Protection Mechanism Failure (693)	24
7	573	Improper Following of Specification by Caller …	20

8 Graph CWEs with more than 10 CWE children

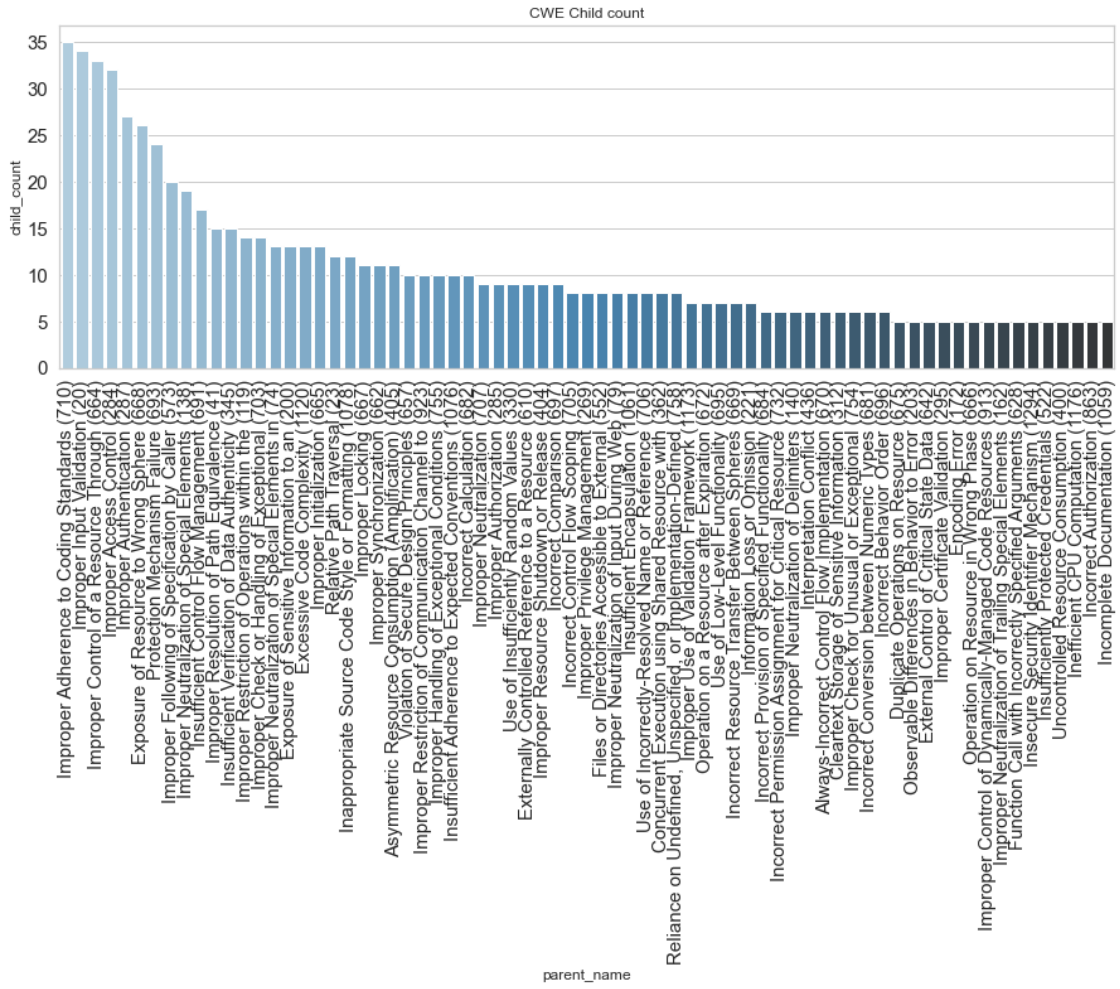
[98]:
```
# ####################
# Graph CWEs with more than 10 CWE children
# ####################
fig = plt.figure(figsize=(15,5))
ax = sns.barplot(x="parent_name", y="child_count", palette="Blues_d",␣
 ↪data=cwe_child_count_gt_n, ci=None);
plt.title('CWE Child count')
plt.setp(ax.get_xticklabels(), rotation=90);
plt.rc('xtick', labelsize=20)
plt.rc('figure', titlesize=15)
```



[99]:
```
fig = plt.figure(figsize=(15,5))
ax = sns.barplot(x="parent_name", y="child_count", palette="Blues_d",␣
 ↪data=cwe_child_count_gt_n2, ci=None);
plt.title('CWE Child count')
plt.setp(ax.get_xticklabels(), rotation=90);
plt.rc('xtick', labelsize=15)
plt.rc('ytick', labelsize=15)
plt.rc('figure', titlesize=15)
```



[100]:
```
fig = plt.figure(figsize=(15,5))
ax = sns.barplot(x="parent_name", y="child_count", palette="Blues_d",␣
 ↪data=cwe_child_count_gt_n3, ci=None);
plt.title('CWE Child count')
plt.setp(ax.get_xticklabels(), rotation=90);
plt.rc('xtick', labelsize=15)
plt.rc('ytick', labelsize=15)
plt.rc('figure', titlesize=15)
```



9 Create CWE Consequence Nodes

[101]:
```
# ######################
# Create CWE Consequence Nodes
# ######################
def combine_lists(list_1, list_2):
    final_result = set()
    for val1 in list_1:
        for val2 in list_2:
            final_result.add(f'{val1}-{val2}')
    return list(final_result)


consquences_set = set()
cwe_consequence_list = {}
```

```
consquences_incomming_cwe_count = {}

for obj in cwe['Weakness_Catalog']['Weaknesses']['Weakness']:
    cwe_id = obj['@ID']

    try:
        consequences = obj['Common_Consequences']['Consequence']
    except KeyError:
#         print(f'{cwe_id} does not have consequence obj')
#         print('----')
        continue

    if not isinstance(consequences, list):
        consequences_list = [consequences]
    else:
        consequences_list = consequences

    for cons in consequences_list:

        scope = cons.get('Scope', 'Unknown Scope')
        if not isinstance(scope, list):
            scope_list = [scope]
        else:
            scope_list = scope

        impact = cons.get('Impact', 'Unknown Impact')
        if not isinstance(impact, list):
            impact_list = [impact]
        else:
            impact_list = impact

        scope_impact_list = combine_lists(scope_list, impact_list)

        likelihood = cons.get('Likelihood', 'Unknown Likelihood')
        if not isinstance(likelihood, list):
            likelihood_list = [likelihood]
        else:
            likelihood_list = likelihood

        scope_impact_likelihood_list =␣
↪combine_lists(scope_impact_list,likelihood_list)

        for val in scope_impact_likelihood_list:
            if val not in consquences_set:
                consquences_set.add(val)
                cql_create_cwe_consequence_node = f"""CREATE (:consequence {{␣
↪consequence_id: "{val}"}})"""
```

```
                run_query(cql_create_cwe_consequence_node)

            cwe_cons_list = cwe_consequence_list.get(cwe_id, [])
            if val not in cwe_cons_list:
                cql_create_relationship = f"""MATCH (cwe1:cwe), (consequence1:␣
↪consequence)
                                        WHERE cwe1.cwe_id = '{cwe_id}' AND␣
↪consequence1.consequence_id = '{val}'
                                        CREATE (cwe1)-[r:causes]->(consequence1)
                                        RETURN type(r)"""
                run_query(cql_create_relationship)
                cwe_cons_list.append(val)
                cwe_consequence_list[cwe_id] = cwe_cons_list
                count = consquences_incomming_cwe_count.get(val, 0)
                count += 1
                consquences_incomming_cwe_count[val] = count
```

[102]:
```
for key,value in consquences_incomming_cwe_count.items():
    cql_update_cwe_node = f"""MATCH (c:consequence {{ consequence_id:␣
↪"{key}"}}) SET c.child_count = {value}"""
    run_query(cql_update_cwe_node)
```

[103]:
```
data = {'consequence_abbreviation': [], 'consequence_id':[], 'child_count':[]}
for key, value in consquences_incomming_cwe_count.items():
    cons_name = key.split('-')
    cons_name_abbr = f'{cons_name[0][:20]}-{cons_name[1][:20]}'

    data['consequence_abbreviation'].append(cons_name_abbr)
    data['consequence_id'].append(key)
    data['child_count'].append(value)

cwe_consequence_child_count_df = pd.DataFrame(data)
cwe_consequence_child_count_df.sort_values(by=['child_count'], ascending=False,␣
↪inplace=True)
cwe_consequence_child_count_df.reset_index(drop=True, inplace=True)
cwe_consequence_child_count_df_gt_n =␣
↪cwe_consequence_child_count_df[cwe_consequence_child_count_df['child_count']␣
↪>= 20]
```

[104]:
```
cwe_consequence_child_count_df_gt_n
```

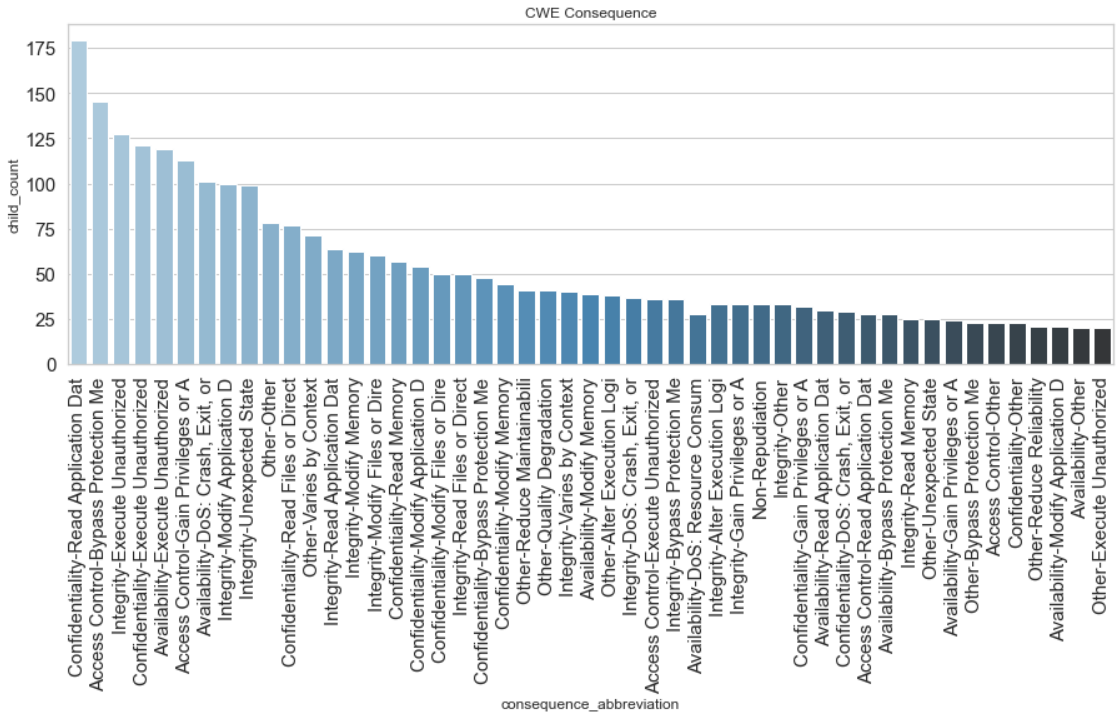
[104]:
```
                consequence_abbreviation  \
0   Confidentiality-Read Application Dat
1    Access Control-Bypass Protection Me
2         Integrity-Execute Unauthorized
3   Confidentiality-Execute Unauthorized
4      Availability-Execute Unauthorized
```

```
5    Access Control-Gain Privileges or A
6      Availability-DoS: Crash, Exit, or
7         Integrity-Modify Application D
8             Integrity-Unexpected State
9                           Other-Other
10 Confidentiality-Read Files or Direct
11              Other-Varies by Context
12        Integrity-Read Application Dat
13              Integrity-Modify Memory
14        Integrity-Modify Files or Dire
15           Confidentiality-Read Memory
16 Confidentiality-Modify Application D
17 Confidentiality-Modify Files or Dire
18        Integrity-Read Files or Direct
19 Confidentiality-Bypass Protection Me
20         Confidentiality-Modify Memory
21            Other-Reduce Maintainabili
22             Other-Quality Degradation
23           Integrity-Varies by Context
24            Availability-Modify Memory
25            Other-Alter Execution Logi
26        Integrity-DoS: Crash, Exit, or
27  Access Control-Execute Unauthorized
28        Integrity-Bypass Protection Me
29     Availability-DoS: Resource Consum
30        Integrity-Alter Execution Logi
31        Integrity-Gain Privileges or A
32                       Non-Repudiation
33                       Integrity-Other
34 Confidentiality-Gain Privileges or A
35     Availability-Read Application Dat
36 Confidentiality-DoS: Crash, Exit, or
37  Access Control-Read Application Dat
38     Availability-Bypass Protection Me
39                  Integrity-Read Memory
40                Other-Unexpected State
41     Availability-DoS: Resource Consum
42     Availability-Gain Privileges or A
43            Other-Bypass Protection Me
44                  Access Control-Other
45     Availability-DoS: Resource Consum
46                Confidentiality-Other
47              Other-Reduce Reliability
48     Availability-Modify Application D
49                    Availability-Other
50            Other-Execute Unauthorized
```

	consequence_id	child_count
0	Confidentiality-Read Application Data-Unknown …	179
1	Access Control-Bypass Protection Mechanism-Unk…	145
2	Integrity-Execute Unauthorized Code or Command…	127
3	Confidentiality-Execute Unauthorized Code or C…	121
4	Availability-Execute Unauthorized Code or Comm…	119
5	Access Control-Gain Privileges or Assume Ident…	113
6	Availability-DoS: Crash, Exit, or Restart-Unkn…	101
7	Integrity-Modify Application Data-Unknown Like…	100
8	Integrity-Unexpected State-Unknown Likelihood	99
9	Other-Other-Unknown Likelihood	78
10	Confidentiality-Read Files or Directories-Unkn…	77
11	Other-Varies by Context-Unknown Likelihood	71
12	Integrity-Read Application Data-Unknown Likeli…	64
13	Integrity-Modify Memory-Unknown Likelihood	62
14	Integrity-Modify Files or Directories-Unknown …	60
15	Confidentiality-Read Memory-Unknown Likelihood	57
16	Confidentiality-Modify Application Data-Unknow…	54
17	Confidentiality-Modify Files or Directories-Un…	50
18	Integrity-Read Files or Directories-Unknown Li…	50
19	Confidentiality-Bypass Protection Mechanism-Un…	48
20	Confidentiality-Modify Memory-Unknown Likelihood	44
21	Other-Reduce Maintainability-Unknown Likelihood	41
22	Other-Quality Degradation-Unknown Likelihood	41
23	Integrity-Varies by Context-Unknown Likelihood	40
24	Availability-Modify Memory-Unknown Likelihood	39
25	Other-Alter Execution Logic-Unknown Likelihood	38
26	Integrity-DoS: Crash, Exit, or Restart-Unknown…	37
27	Access Control-Execute Unauthorized Code or Co…	36
28	Integrity-Bypass Protection Mechanism-Unknown …	36
29	Availability-DoS: Resource Consumption (CPU)-U…	36
30	Integrity-Alter Execution Logic-Unknown Likeli…	33
31	Integrity-Gain Privileges or Assume Identity-U…	33
32	Non-Repudiation-Hide Activities-Unknown Likeli…	33
33	Integrity-Other-Unknown Likelihood	33
34	Confidentiality-Gain Privileges or Assume Iden…	32
35	Availability-Read Application Data-Unknown Lik…	30
36	Confidentiality-DoS: Crash, Exit, or Restart-U…	29
37	Access Control-Read Application Data-Unknown L…	28
38	Availability-Bypass Protection Mechanism-Unkno…	28
39	Integrity-Read Memory-Unknown Likelihood	25
40	Other-Unexpected State-Unknown Likelihood	25
41	Availability-DoS: Resource Consumption (Memory…	25
42	Availability-Gain Privileges or Assume Identit…	24
43	Other-Bypass Protection Mechanism-Unknown Like…	23
44	Access Control-Other-Unknown Likelihood	23
45	Availability-DoS: Resource Consumption (Other)…	23

```
46          Confidentiality-Other-Unknown Likelihood          23
47       Other-Reduce Reliability-Unknown Likelihood          21
48 Availability-Modify Application Data-Unknown L…          21
49             Availability-Other-Unknown Likelihood          20
50 Other-Execute Unauthorized Code or Commands-Un…          20
```

[105]:
```
fig = plt.figure(figsize=(15,5))
ax = sns.barplot(x="consequence_abbreviation", y="child_count",␣
↪palette="Blues_d", data=cwe_consequence_child_count_df_gt_n, ci=None);
plt.title('CWE Consequence')
plt.setp(ax.get_xticklabels(), rotation=90);
plt.rc('xtick', labelsize=15)
plt.rc('ytick', labelsize=15)
plt.rc('figure', titlesize=15)
```



10 Create CWE Mode of Introduction Nodes

[106]:
```
# ####################
# Create CWE Mode of Introduction Nodes
# ####################
modes_of_intro_set = set()
modes_of_intro_cwe_list = {}
modes_of_intro_cwe_count = {}
```

```
for obj in cwe['Weakness_Catalog']['Weaknesses']['Weakness']:
    cwe_id = obj['@ID']
    try:
        modes_of_intro = obj['Modes_Of_Introduction']['Introduction']
    except KeyError:
#         print(f'{cwe_id} does not have modes_of_introduction')
        continue

    if not isinstance(modes_of_intro, list):
        modes_of_intro_list = [modes_of_intro]
    else:
        modes_of_intro_list = modes_of_intro

    for val in modes_of_intro_list:
        try:
            phase = val['Phase']
        except KeyError:
            continue
        except:
            print(val)
            raise ValueError

        if phase not in modes_of_intro_set:
            cql_create_cwe_modes_of_intro_node = f"""CREATE (:
↪mode_of_introduction {{ mode_of_intro_id: "{phase}"}})"""
            run_query(cql_create_cwe_modes_of_intro_node)
            modes_of_intro_set.add(phase)


        modes_of_intro_cwe_val = modes_of_intro_cwe_list.get(cwe_id, [])
        if phase not in modes_of_intro_cwe_val:
            cql_create_relationship = f"""MATCH (cwe1:cwe), (intro1:
↪mode_of_introduction)
                          WHERE cwe1.cwe_id = '{cwe_id}' AND intro1.
↪mode_of_intro_id = '{phase}'
                          CREATE (cwe1)-[r:introduced_in]->(intro1)
                          RETURN type(r)"""

            run_query(cql_create_relationship)
            count = modes_of_intro_cwe_count.get(phase, 0)
            count += 1
            modes_of_intro_cwe_count[phase] = count
            modes_of_intro_cwe_val.append(phase)
            modes_of_intro_cwe_list[cwe_id] = modes_of_intro_cwe_val
```

[107]:
```
for key,value in modes_of_intro_cwe_count.items():
    cql_update_cwe_node = f"""MATCH (c:mode_of_introduction {{ mode_of_intro_id:
 ↪ "{key}"}}) SET c.child_count = {value}"""
    run_query(cql_update_cwe_node)
```

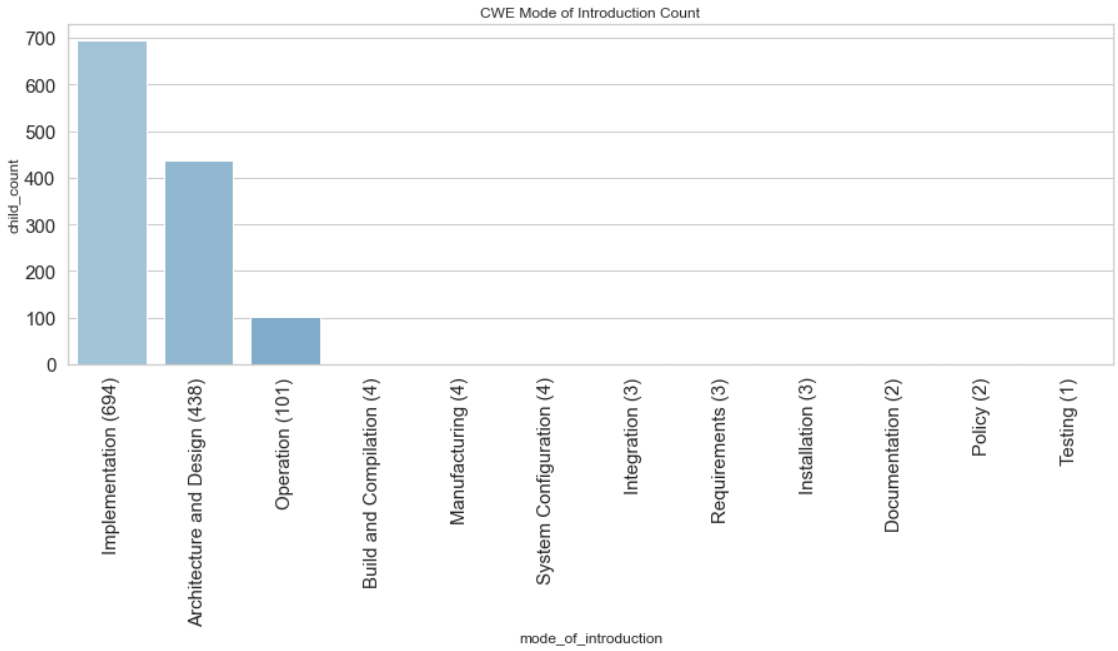
[108]:
```
data = {'mode_of_introduction':[], 'child_count':[]}
for key, value in modes_of_intro_cwe_count.items():
    data['mode_of_introduction'].append(f'{key} ({value})')
    data['child_count'].append(value)

modes_of_intro_cwe_count_df = pd.DataFrame(data)
modes_of_intro_cwe_count_df.sort_values(by=['child_count'], ascending=False,␣
 ↪inplace=True)
modes_of_intro_cwe_count_df.reset_index(drop=True, inplace=True)
```

[109]:
```
modes_of_intro_cwe_count_df
```

[109]:

	mode_of_introduction	child_count
0	Implementation (694)	694
1	Architecture and Design (438)	438
2	Operation (101)	101
3	Build and Compilation (4)	4
4	Manufacturing (4)	4
5	System Configuration (4)	4
6	Integration (3)	3
7	Requirements (3)	3
8	Installation (3)	3
9	Documentation (2)	2
10	Policy (2)	2
11	Testing (1)	1

[110]:
```
fig = plt.figure(figsize=(15,5))
ax = sns.barplot(x="mode_of_introduction", y="child_count", palette="Blues_d",␣
 ↪data=modes_of_intro_cwe_count_df, ci=None);
plt.title('CWE Mode of Introduction Count')
plt.setp(ax.get_xticklabels(), rotation=90);
plt.rc('xtick', labelsize=15)
plt.rc('ytick', labelsize=15)
plt.rc('figure', titlesize=15)
```



11 CWE Time series

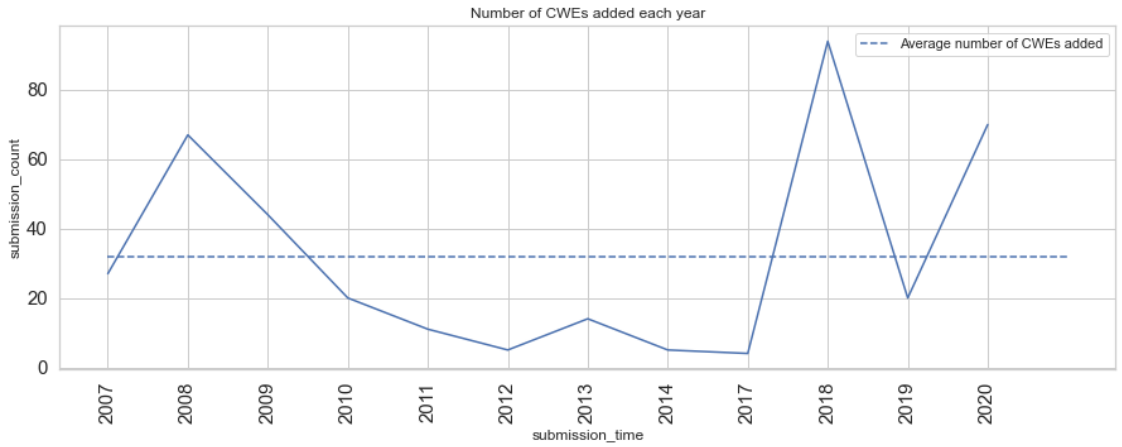
[111]:
```
# ####################
# CWE Time series
# ####################
data = {'cwe_id':[], 'cwe_name':[], 'submission_time':[]}

for obj in cwe['Weakness_Catalog']['Weaknesses']['Weakness']:
    cwe_id = obj['@ID']
    cwe_name = obj['@Name']
    submission_time = obj['Content_History']['Submission']['Submission_Date']
    submission_year = submission_time.split('-')[0]
    data['cwe_id'].append(cwe_id)
    data['cwe_name'].append(cwe_name)
    data['submission_time'].append(submission_year)

cwe_submission_time_df = pd.DataFrame(data)
```

[112]:
```
cwe_submission_time_groupby = cwe_submission_time_df.
 ↪groupby(by=['submission_time']).count().reset_index(drop=False)
cwe_submission_time_groupby.rename({'cwe_id':
 ↪'submission_count'},axis='columns', inplace=True)
filtered_df =␣
 ↪cwe_submission_time_groupby[cwe_submission_time_groupby['submission_count']␣
 ↪< 200]
```

[113]:
```
filtered_df['submission_count'].describe()
```

[113]:
```
count    12.000000
mean     31.750000
std      30.115309
min       4.000000
25%       9.500000
50%      20.000000
75%      49.750000
max      94.000000
Name: submission_count, dtype: float64
```

[114]:
```
fig = plt.figure(figsize=(15,5))
ax = sns.lineplot(data=filtered_df, x="submission_time", y="submission_count");
plt.hlines(y=32, xmin=0, xmax=12, colors='b', linestyles='--', label='Average␣
 ↪number of CWEs added')
plt.title('Number of CWEs added each year')
plt.setp(ax.get_xticklabels(), rotation=90);
plt.rc('xtick', labelsize=15)
plt.rc('ytick', labelsize=15)
plt.rc('figure', titlesize=15)
ax.legend();
```



[115]:
```
cwe_submission_time_groupby
```

[115]:

	submission_time	submission_count	cwe_name
0	2006	533	533
1	2007	27	27
2	2008	67	67
3	2009	44	44
4	2010	20	20

5	2011	11	11
6	2012	5	5
7	2013	14	14
8	2014	5	5
9	2017	4	4
10	2018	94	94
11	2019	20	20
12	2020	70	70