project

July 29, 2025

0.1 Original Dataset

[1]:
```
import pandas as pd
import os

# Folder path
dataset_path = '../data/original-datasets'

# Required columns
required_columns = ['CC', 'LCOM5', 'WMC', 'CBO', 'RFC', 'DIT',        'NOC',␣
 ↪'LOC', 'NPM', 'isExistBug']

# List to collect all valid DataFrames
df_list = []

# Iterate through all CSV files in the folder
for filename in os.listdir(dataset_path):
    if filename.endswith('.csv'):
        file_path = os.path.join(dataset_path, filename)
        try:
            df = pd.read_csv(file_path)

            # Check if all required columns are present
            if all(col in df.columns for col in required_columns):
                # Extract project name from the filename (without extension)
                project_name = os.path.splitext(filename)[0]
                df = df[required_columns].copy()  # Keep only required columns
                df['project'] = project_name      # Add project name as a column
                df_list.append(df)
            else:
                print(f"Missing required columns: {filename}")
        except Exception as e:
            print(f"Error while reading file: {filename} | {e}")

# If at least one file was loaded successfully, concatenate them
if df_list:
    combined_df = pd.concat(df_list, ignore_index=True)
    print(f"Total number of rows: {len(combined_df)}")
```

```
    print(combined_df.head())
else:
    print("No valid file found. Please check the files and column names.")
```

```
Total number of rows: 37630
    CC  LCOM5  WMC  CBO  RFC  DIT  NOC  LOC  NPM  isExistBug  \
0  0.0      6   18    4   20    0    0  243   13           0
1  0.0      0    5    1    5    0    0   71    5           0
2  0.0      1   16    6   11    0    0   59    3           0
3  0.0      2   14    3   11    0    2  308   10           0
4  0.0      0    2    0    2    0    0   27    2           0

                 project
0  BugPrediction_Eclipse
1  BugPrediction_Eclipse
2  BugPrediction_Eclipse
3  BugPrediction_Eclipse
4  BugPrediction_Eclipse
```

[2]:
```
# Project-Level Bug Statistics Summary Table

from tabulate import tabulate

# Create bug statistics table per project
bug_summary = combined_df.groupby('project').agg(
    total_instances=('isExistBug', 'count'),
    bug_instances=('isExistBug', 'sum')
)

# Calculate bug rate as a percentage
bug_summary['bug_rate_percent'] = 100 * bug_summary['bug_instances'] /␣
 ↪bug_summary['total_instances']

# Round the percentage
bug_summary['bug_rate_percent'] = bug_summary['bug_rate_percent'].round(2)

# Sort by bug rate
bug_summary = bug_summary.sort_values('bug_rate_percent', ascending=False).
 ↪reset_index()

# Print the table
print(tabulate(bug_summary, headers='keys', tablefmt='fancy_grid',␣
 ↪showindex=False))
```

```
 project                    total_instances    bug_instances
bug_rate_percent
```

Promise_xalan27	909	898	98.79
Promise_log4j	205	189	92.2
Promise_xerces	546	396	72.53
Promise_poi30	442	281	63.57
Promise_lucene24	339	203	59.88
Promise_ckjm18	9	5	55.56
BugPrediction_Equinox	319	126	39.5
Promise_velocity16	228	78	34.21
Promise_synapse12	256	86	33.59
Github_Android	73	20	27.4
Github_Netty	1143	271	23.71
Promise_ant14	745	166	22.28

BugPrediction_Eclipse	997	206	20.66
Promise_camel16	927	188	20.28
Promise_pbeans2	51	10	19.61
Github_mcMMO	301	57	18.94
Github_BroadleafCommerce	1593	292	18.33
Github_orientdb	1847	280	15.16
BugPrediction_Mylyn	1405	209	14.88
BugPrediction_PDE	1491	208	13.95
Github_oryx	533	74	13.88
Github_mapdb	331	40	12.08
Github_Elasticsearch	5908	678	11.48
Promise_ivy20	352	40	11.36

```
  Github_hazelcast                3412              380
11.14

  BugPrediction_lucene             670               63
9.4

  Github_titan                    1468               96
6.54

  Promise_forrest08                 32                2
6.25

  Github_JUnit                     731               35
4.79

  Github_antlr4                    479               21
4.38

  Github_ceylon                   1610               68
4.22

  Promise_jedit43                  492               11
2.24

  Github_Neo4j                    5899               58
0.98

  Github_mct17                    1887                9
0.48
```

[3]:
```
# Z-Score Analysis of Bug Rates Across Projects

from scipy.stats import zscore
from tabulate import tabulate
```

```python
# Calculate Z-score
bug_summary['z_score'] = zscore(bug_summary['bug_rate_percent'])

# Select necessary columns and sort by Z-Score
zscore_table = bug_summary[['project', 'bug_rate_percent', 'z_score']].
 ↪sort_values(by='z_score', ascending=False)

# Print the table
print(tabulate(
    zscore_table,
    headers=['Project', 'Bug Rate (%)', 'Z-Score'],
    tablefmt='fancy_grid',
    showindex=False,
    floatfmt=".2f"
))
```

Project	Bug Rate (%)	Z-Score
Promise_xalan27	98.79	2.92
Promise_log4j	92.20	2.66
Promise_xerces	72.53	1.88
Promise_poi30	63.57	1.52
Promise_lucene24	59.88	1.37
Promise_ckjm18	55.56	1.20
BugPrediction_Equinox	39.50	0.56
Promise_velocity16	34.21	0.35
Promise_synapse12	33.59	0.33
Github_Android	27.40	0.08
Github_Netty	23.71	-0.07
Promise_ant14	22.28	-0.12
BugPrediction_Eclipse	20.66	-0.19
Promise_camel16	20.28	-0.20

```
Promise_pbeans2                 19.61       -0.23
Github_mcMMO                    18.94       -0.26
Github_BroadleafCommerce        18.33       -0.28
Github_orientdb                 15.16       -0.41
BugPrediction_Mylyn             14.88       -0.42
BugPrediction_PDE               13.95       -0.46
Github_oryx                     13.88       -0.46
Github_mapdb                    12.08       -0.53
Github_Elasticsearch            11.48       -0.55
Promise_ivy20                   11.36       -0.56
Github_hazelcast                11.14       -0.57
BugPrediction_lucene             9.40       -0.64
Github_titan                     6.54       -0.75
Promise_forrest08                6.25       -0.76
Github_JUnit                     4.79       -0.82
Github_antlr4                    4.38       -0.84
Github_ceylon                    4.22       -0.84
Promise_jedit43                  2.24       -0.92
Github_Neo4j                     0.98       -0.97
Github_mct17                     0.48       -0.99
```

[4]:
```python
# Outlier Projects Based on Bug Rate Z-Scores
from tabulate import tabulate

# 1. Filter out projects where the absolute z-score is greater than 2
outlier_projects_df = bug_summary[bug_summary['z_score'].abs() > 2][['project',␣
 ↪'bug_rate_percent', 'z_score']].copy()
```

```
outlier_projects = outlier_projects_df['project'].tolist()

# 2. Keep only the non-outlier projects
filtered_combined_df = combined_df[~combined_df['project'].
 ↪isin(outlier_projects)].copy()

# 3. Summary of the filtering
print(f"Number of removed outlier projects: {len(outlier_projects)}")
print(f"Number of remaining projects: {filtered_combined_df['project'].
 ↪nunique()}")
print(f"Total number of rows after filtering: {len(filtered_combined_df)}")

# 4. Show removed projects with reason (z-score)
print("Outlier Projects (|z-score| > 2):")
print(tabulate(
    outlier_projects_df.sort_values(by='z_score', ascending=False),
    headers=['Project', 'Bug Rate (%)', 'Z-Score'],
    tablefmt='fancy_grid',
    floatfmt=".2f",
    showindex=False
))
```

```
Number of removed outlier projects: 2
Number of remaining projects: 32
Total number of rows after filtering: 36516
Outlier Projects (|z-score| > 2):

 Project             Bug Rate (%)     Z-Score

 Promise_xalan27            98.79        2.92

 Promise_log4j              92.20        2.66
```

[5]:
```
# Listing All Project Names from CSV Files in a Directory
import os

# Folder path
dataset_path = "../data/original-datasets"

# Get CSV filenames and remove the .csv extension
project_names = [
    os.path.splitext(filename)[0]
    for filename in os.listdir(dataset_path)
    if filename.endswith(".csv")
]
```

```python
# Print the list
print("Total number of projects:", len(project_names))
print("Project names:")
for name in project_names:
    print("-", name)
```

```
Total number of projects: 34
Project names:
- BugPrediction_Eclipse
- BugPrediction_Equinox
- BugPrediction_lucene
- BugPrediction_Mylyn
- BugPrediction_PDE
- Github_Android
- Github_antlr4
- Github_BroadleafCommerce
- Github_ceylon
- Github_Elasticsearch
- Github_hazelcast
- Github_JUnit
- Github_mapdb
- Github_mcMMO
- Github_mct17
- Github_Neo4j
- Github_Netty
- Github_orientdb
- Github_oryx
- Github_titan
- Promise_ant14
- Promise_camel16
- Promise_ckjm18
- Promise_forrest08
- Promise_ivy20
- Promise_jedit43
- Promise_log4j
- Promise_lucene24
- Promise_pbeans2
- Promise_poi30
- Promise_synapse12
- Promise_velocity16
- Promise_xalan27
- Promise_xerces
```

0.2 Computation Dataset Complexity Metrics

[6]:
```python
# Batch Computation and Export of Dataset Complexity Metrics for Multiple␣
↪Projects

import os
import pandas as pd
from problexity import ComplexityCalculator
from sklearn.preprocessing import LabelEncoder

# Input and output folder paths
input_folder = "../data/original-datasets/"
output_folder = "../data/originaldata-complexitymetrics/"

# Create output folder if it doesn't exist
os.makedirs(output_folder, exist_ok=True)

# Get all project names by removing .csv extension
project_names = [
    os.path.splitext(filename)[0]
    for filename in os.listdir(input_folder)
    if filename.endswith(".csv")
]

# Process each project
for project_name in project_names:
    input_file = os.path.join(input_folder, f"{project_name}.csv")
    output_file = os.path.join(output_folder, f"CM_{project_name}.csv")

    if not os.path.exists(output_file):
        print(f"Calculating metrics for {project_name}...")

        try:
            # Read dataset
            df = pd.read_csv(input_file)

            # Separate features and target
            X = df.drop(columns=["isExistBug"]).astype(float)
            y = LabelEncoder().fit_transform(df["isExistBug"])

            # Compute complexity metrics
            cc = ComplexityCalculator()
            cc.fit(X, y)
            report = cc.report()
            metrics = report["complexities"]
            metrics["score"] = report["score"]
```

```
            # Convert to DataFrame
            df_metrics = pd.DataFrame([metrics])
            df_metrics.insert(0, "project_name", project_name)

            # Save to CSV
            df_metrics.to_csv(output_file, index=False)
            print(f"{output_file} created successfully.")

        except Exception as e:
            print(f"Error processing {project_name}: {e}")

    else:
        print(f"{output_file} already exists. Skipping.")
```

```
Calculating metrics for BugPrediction_Eclipse…
../data/originaldata-complexitymetrics/CM_BugPrediction_Eclipse.csv created
successfully.
Calculating metrics for BugPrediction_Equinox…
../data/originaldata-complexitymetrics/CM_BugPrediction_Equinox.csv created
successfully.
Calculating metrics for BugPrediction_lucene…
../data/originaldata-complexitymetrics/CM_BugPrediction_lucene.csv created
successfully.
Calculating metrics for BugPrediction_Mylyn…
../data/originaldata-complexitymetrics/CM_BugPrediction_Mylyn.csv created
successfully.
Calculating metrics for BugPrediction_PDE…
../data/originaldata-complexitymetrics/CM_BugPrediction_PDE.csv created
successfully.
Calculating metrics for Github_Android…
../data/originaldata-complexitymetrics/CM_Github_Android.csv created
successfully.
Calculating metrics for Github_antlr4…
../data/originaldata-complexitymetrics/CM_Github_antlr4.csv created
successfully.
Calculating metrics for Github_BroadleafCommerce…
../data/originaldata-complexitymetrics/CM_Github_BroadleafCommerce.csv created
successfully.
Calculating metrics for Github_ceylon…
../data/originaldata-complexitymetrics/CM_Github_ceylon.csv created
successfully.
Calculating metrics for Github_Elasticsearch…
../data/originaldata-complexitymetrics/CM_Github_Elasticsearch.csv created
successfully.
Calculating metrics for Github_hazelcast…
../data/originaldata-complexitymetrics/CM_Github_hazelcast.csv created
successfully.
```

```
Calculating metrics for Github_JUnit…
../data/originaldata-complexitymetrics/CM_Github_JUnit.csv created successfully.
Calculating metrics for Github_mapdb…
../data/originaldata-complexitymetrics/CM_Github_mapdb.csv created successfully.
Calculating metrics for Github_mcMMO…
../data/originaldata-complexitymetrics/CM_Github_mcMMO.csv created successfully.
Calculating metrics for Github_mct17…
../data/originaldata-complexitymetrics/CM_Github_mct17.csv created successfully.
Calculating metrics for Github_Neo4j…
../data/originaldata-complexitymetrics/CM_Github_Neo4j.csv created successfully.
Calculating metrics for Github_Netty…
../data/originaldata-complexitymetrics/CM_Github_Netty.csv created successfully.
Calculating metrics for Github_orientdb…
../data/originaldata-complexitymetrics/CM_Github_orientdb.csv created
successfully.
Calculating metrics for Github_oryx…
../data/originaldata-complexitymetrics/CM_Github_oryx.csv created successfully.
Calculating metrics for Github_titan…
../data/originaldata-complexitymetrics/CM_Github_titan.csv created successfully.
Calculating metrics for Promise_ant14…
../data/originaldata-complexitymetrics/CM_Promise_ant14.csv created
successfully.
Calculating metrics for Promise_camel16…
../data/originaldata-complexitymetrics/CM_Promise_camel16.csv created
successfully.
Calculating metrics for Promise_ckjm18…

C:\Users\ramaz\AppData\Roaming\Python\Python313\site-
packages\problexity\classification\feature_based.py:45: RuntimeWarning: invalid
value encountered in divide
  r_all = l/m
C:\Users\ramaz\AppData\Roaming\Python\Python313\site-
packages\problexity\classification\feature_based.py:141: RuntimeWarning: invalid
value encountered in divide
  return np.nanprod(f_overlap/f_range)

../data/originaldata-complexitymetrics/CM_Promise_ckjm18.csv created
successfully.
Calculating metrics for Promise_forrest08…
../data/originaldata-complexitymetrics/CM_Promise_forrest08.csv created
successfully.
Calculating metrics for Promise_ivy20…
../data/originaldata-complexitymetrics/CM_Promise_ivy20.csv created
successfully.
Calculating metrics for Promise_jedit43…
../data/originaldata-complexitymetrics/CM_Promise_jedit43.csv created
successfully.
Calculating metrics for Promise_log4j…
../data/originaldata-complexitymetrics/CM_Promise_log4j.csv created
```

```
successfully.
Calculating metrics for Promise_lucene24…
../data/originaldata-complexitymetrics/CM_Promise_lucene24.csv created
successfully.
Calculating metrics for Promise_pbeans2…
../data/originaldata-complexitymetrics/CM_Promise_pbeans2.csv created
successfully.
Calculating metrics for Promise_poi30…
../data/originaldata-complexitymetrics/CM_Promise_poi30.csv created
successfully.
Calculating metrics for Promise_synapse12…
../data/originaldata-complexitymetrics/CM_Promise_synapse12.csv created
successfully.
Calculating metrics for Promise_velocity16…
../data/originaldata-complexitymetrics/CM_Promise_velocity16.csv created
successfully.
Calculating metrics for Promise_xalan27…
../data/originaldata-complexitymetrics/CM_Promise_xalan27.csv created
successfully.
Calculating metrics for Promise_xerces…
../data/originaldata-complexitymetrics/CM_Promise_xerces.csv created
successfully.
```

0.3 Merge Complexity Metrics

[7]:
```python
# Merging Project-Level Complexity Metric Files into a Single CSV
import os
import pandas as pd

# Input folder and output file path
input_folder = "../data/originaldata-complexitymetrics/"
output_folder = "../data/results/originaldata-results/"
output_file = os.path.join(output_folder, "merged_complexity_metrics.csv")

# Create output folder if it doesn't exist
os.makedirs(output_folder, exist_ok=True)

# Initialize an empty list
df_list = []

# Read all CSV files in the input folder that start with "CM_"
for filename in os.listdir(input_folder):
    if filename.startswith("CM_") and filename.endswith(".csv"):
        filepath = os.path.join(input_folder, filename)
        df = pd.read_csv(filepath)
        df_list.append(df)
```

```
# Concatenate all dataframes
merged_df = pd.concat(df_list, ignore_index=True)

# Save the merged dataframe to CSV
merged_df.to_csv(output_file, index=False)
print(f"All complexity metrics merged into: {output_file}")
```

```
All complexity metrics merged into: ../data/results/originaldata-
results/merged_complexity_metrics.csv
```

0.4 Feature Selection Stability Metrics

[9]:
```
# Automated Feature Selection and Stability Evaluation Across Multiple Projects
import os
import sys
import numpy as np
import pandas as pd
from sklearn.preprocessing import LabelEncoder
from sklearn.feature_selection import SelectKBest, chi2, mutual_info_classif
from sklearn.linear_model import LogisticRegression
from skrebate import ReliefF
from sklearn.model_selection import StratifiedShuffleSplit
import random

# Add 'stability' module to path
sys.path.append(os.path.abspath('stability'))
import stability as st

# Folder configuration
dataset_folder = "../data/original-datasets"
output_dir = "../data/originaldata-fs-stability-metrics"
os.makedirs(output_dir, exist_ok=True)

# Feature and target definitions
features = ['CC', 'LCOM5', 'WMC', 'CBO', 'RFC', 'DIT', 'NOC', 'LOC', 'NPM']
target = 'isExistBug'

# Feature selection parameters
k = 3
n_iter = 30
random_state = None

# Helper function: convert feature selection results to binary matrix
def fs_result_to_binary_matrix(fs_result_list, all_features):
    return np.array([[1 if feat in selected else 0 for feat in all_features]␣
 ↪for selected in fs_result_list])
```

```
# Process each CSV file
for filename in os.listdir(dataset_folder):
    if filename.endswith(".csv"):
        project_name = os.path.splitext(filename)[0]
        file_path = os.path.join(dataset_folder, filename)

        print(f"\nProcessing project: {project_name}")

        # 1. Load dataset
        df = pd.read_csv(file_path)
        X = df[features]
        y = LabelEncoder().fit_transform(df[target])

        splitter = StratifiedShuffleSplit(n_splits=n_iter, test_size=0.2,␣
↪random_state=random_state)
        fs_results = {method: [] for method in ["Chi2", "MutualInfo",␣
↪"ReliefF", "Lasso"]}

        # 2. Perform feature selection
        for _, (train_idx, _) in enumerate(splitter.split(X, y), start=1):
            X_sample = X.iloc[train_idx]
            y_sample = y[train_idx]

            # Chi2
            chi2_selector = SelectKBest(score_func=chi2, k=k)
            chi2_selector.fit(X_sample, y_sample)
            fs_results["Chi2"].append(X_sample.columns[chi2_selector.
↪get_support()].tolist())

            # Mutual Info
            mi_selector = SelectKBest(score_func=mutual_info_classif, k=k)
            mi_selector.fit(X_sample, y_sample)
            fs_results["MutualInfo"].append(X_sample.columns[mi_selector.
↪get_support()].tolist())

            # ReliefF
            relief_selector = ReliefF(n_features_to_select=k)
            relief_selector.fit(X_sample.values, y_sample)
            top_relief = relief_selector.top_features_[:k]
            fs_results["ReliefF"].append(X_sample.columns[top_relief].tolist())

            # Lasso
            lasso_model = LogisticRegression(penalty='l1', solver='liblinear',␣
↪random_state=random.randint(0, 9999))
            lasso_model.fit(X_sample, y_sample)
            lasso_features = X_sample.columns[lasso_model.coef_[0] != 0].
↪tolist()
```

```
            fs_results["Lasso"].append(lasso_features[:k] if␣
 ↪len(lasso_features) > k else lasso_features)

        # 3. Save selected features to CSV (if not already exists)
        for method, results in fs_results.items():
            out_path = f"{output_dir}/{project_name}_{method}_selected_features.
 ↪csv"
            if not os.path.exists(out_path):
                df_method = pd.DataFrame(results)
                df_method.index = [f"Run_{i+1}" for i in range(n_iter)]
                df_method.columns = [f"Feature_{j+1}" for j in range(df_method.
 ↪shape[1])]
                df_method.insert(0, "Project", project_name)
                df_method.to_csv(out_path, index_label="Run")
            else:
                print(f"Skipped existing file: {out_path}")

        # 4. Compute stability scores and save to CSV (if not already exists)
        stab_path = f"{output_dir}/{project_name}_feature_selection_stability.
 ↪csv"
        if not os.path.exists(stab_path):
            stability_records = []
            for method in fs_results:
                Z = fs_result_to_binary_matrix(fs_results[method], features)
                stab = st.getVarianceofStability(Z)
                ci = st.confidenceIntervals(Z)
                stability_records.append({
                    "Project": project_name,
                    "Method": method,
                    "Stability": round(stab['stability'], 4),
                    "CI_Lower": round(ci['lower'], 4),
                    "CI_Upper": round(ci['upper'], 4)
                })
            df_stability = pd.DataFrame(stability_records)
            df_stability.to_csv(stab_path, index=False)
        else:
            print(f"Skipped existing stability file: {stab_path}")

print("\nAll projects processed. Feature selection results and stability scores␣
 ↪are saved.")
```

```
Processing project: BugPrediction_Eclipse

Processing project: BugPrediction_Equinox

Processing project: BugPrediction_lucene
```

```
Processing project: BugPrediction_Mylyn

Processing project: BugPrediction_PDE

Processing project: Github_Android

Processing project: Github_antlr4

Processing project: Github_BroadleafCommerce

Processing project: Github_ceylon

Processing project: Github_Elasticsearch

Processing project: Github_hazelcast

Processing project: Github_JUnit

Processing project: Github_mapdb

Processing project: Github_mcMMO

Processing project: Github_mct17

Processing project: Github_Neo4j

Processing project: Github_Netty

Processing project: Github_orientdb

Processing project: Github_oryx

Processing project: Github_titan

Processing project: Promise_ant14

Processing project: Promise_camel16

Processing project: Promise_ckjm18

Processing project: Promise_forrest08

Processing project: Promise_ivy20

Processing project: Promise_jedit43

Processing project: Promise_log4j
```

```
Processing project: Promise_lucene24

Processing project: Promise_pbeans2

Processing project: Promise_poi30

Processing project: Promise_synapse12

Processing project: Promise_velocity16

Processing project: Promise_xalan27

C:\Users\ramaz\AppData\Roaming\Python\Python313\site-
packages\sklearn\svm\_base.py:1249: ConvergenceWarning: Liblinear failed to
converge, increase the number of iterations.
  warnings.warn(
C:\Users\ramaz\AppData\Roaming\Python\Python313\site-
packages\sklearn\svm\_base.py:1249: ConvergenceWarning: Liblinear failed to
converge, increase the number of iterations.
  warnings.warn(
C:\Users\ramaz\AppData\Roaming\Python\Python313\site-
packages\sklearn\svm\_base.py:1249: ConvergenceWarning: Liblinear failed to
converge, increase the number of iterations.
  warnings.warn(
C:\Users\ramaz\AppData\Roaming\Python\Python313\site-
packages\sklearn\svm\_base.py:1249: ConvergenceWarning: Liblinear failed to
converge, increase the number of iterations.
  warnings.warn(
C:\Users\ramaz\AppData\Roaming\Python\Python313\site-
packages\sklearn\svm\_base.py:1249: ConvergenceWarning: Liblinear failed to
converge, increase the number of iterations.
  warnings.warn(
C:\Users\ramaz\AppData\Roaming\Python\Python313\site-
packages\sklearn\svm\_base.py:1249: ConvergenceWarning: Liblinear failed to
converge, increase the number of iterations.
  warnings.warn(


Processing project: Promise_xerces

All projects processed. Feature selection results and stability scores are
saved.
```

0.5 Merge Feature Selection Stability Metrics

[10]:
```
# Merging and Pivoting Feature Selection Stability Reports with Custom Project␣
 ↪Order
import os
import pandas as pd

# Input and output folders
input_folder = "../data/originaldata-fs-stability-metrics"
output_folder = "../data/results/originaldata-results"
os.makedirs(output_folder, exist_ok=True)

# Custom project order (defined manually)
custom_order = [
    "BugPrediction_Eclipse", "BugPrediction_Equinox", "BugPrediction_lucene",␣
 ↪"BugPrediction_Mylyn",
    "BugPrediction_PDE", "Github_Android", "Github_antlr4",␣
 ↪"Github_BroadleafCommerce", "Github_ceylon",
    "Github_Elasticsearch", "Github_hazelcast", "Github_JUnit", "Github_mapdb",␣
 ↪"Github_mcMMO",
    "Github_mct17", "Github_Neo4j", "Github_Netty", "Github_orientdb",␣
 ↪"Github_oryx", "Github_titan",
    "Promise_ant14", "Promise_camel16", "Promise_ckjm18", "Promise_forrest08",␣
 ↪"Promise_ivy20",
    "Promise_jedit43", "Promise_log4j", "Promise_lucene24", "Promise_pbeans2",␣
 ↪"Promise_poi30",
    "Promise_synapse12", "Promise_velocity16", "Promise_xalan27",␣
 ↪"Promise_xerces"
]

# Read and merge all CSV files
df_list = []
for filename in sorted(os.listdir(input_folder)):
    if filename.endswith("_feature_selection_stability.csv"):
        file_path = os.path.join(input_folder, filename)
        df = pd.read_csv(file_path)
        df_list.append(df)

merged_df = pd.concat(df_list, ignore_index=True)

# Keep only needed columns
merged_df = merged_df[["Project", "Method", "Stability"]]

# Pivot: each method becomes a column
pivot_df = merged_df.pivot(index="Project", columns="Method",␣
 ↪values="Stability").reset_index()
```

```
# Reorder method columns if needed
desired_order = ["Project", "Chi2", "MutualInfo", "ReliefF", "Lasso"]
pivot_df = pivot_df[desired_order]

# Sort rows by custom project order
pivot_df["Project"] = pd.Categorical(pivot_df["Project"],␣
 ↪categories=custom_order, ordered=True)
pivot_df = pivot_df.sort_values("Project").reset_index(drop=True)

# Save result
output_path = os.path.join(output_folder, "merged_feature_selection_stability.
 ↪csv")
pivot_df.to_csv(output_path, index=False)

print(f"Merged and ordered stability matrix saved to: {output_path}")
```

```
Merged and ordered stability matrix saved to: ../data/results/originaldata-
results\merged_feature_selection_stability.csv
```

0.6 Merge Complexity Metrics and Stability Measures

[11]:
```
import pandas as pd

# Load both CSV files
complexity_path = "../data/results/originaldata-results/
 ↪merged_complexity_metrics.csv"
stability_path = "../data/results/originaldata-results/
 ↪merged_feature_selection_stability.csv"

df_complexity = pd.read_csv(complexity_path)
df_stability = pd.read_csv(stability_path)

# Rename 'Project' column in stability to match 'project_name'
df_stability = df_stability.rename(columns={"Project": "project_name"})

# Merge on project_name
merged_df = pd.merge(df_complexity, df_stability, on="project_name",␣
 ↪how="inner")

# Save to CSV
merged_output_path = "../data/results/originaldata-results/
 ↪merged_complexity_and_stability.csv"
merged_df.to_csv(merged_output_path, index=False)

print("Merged dataset saved to:", merged_output_path)
```

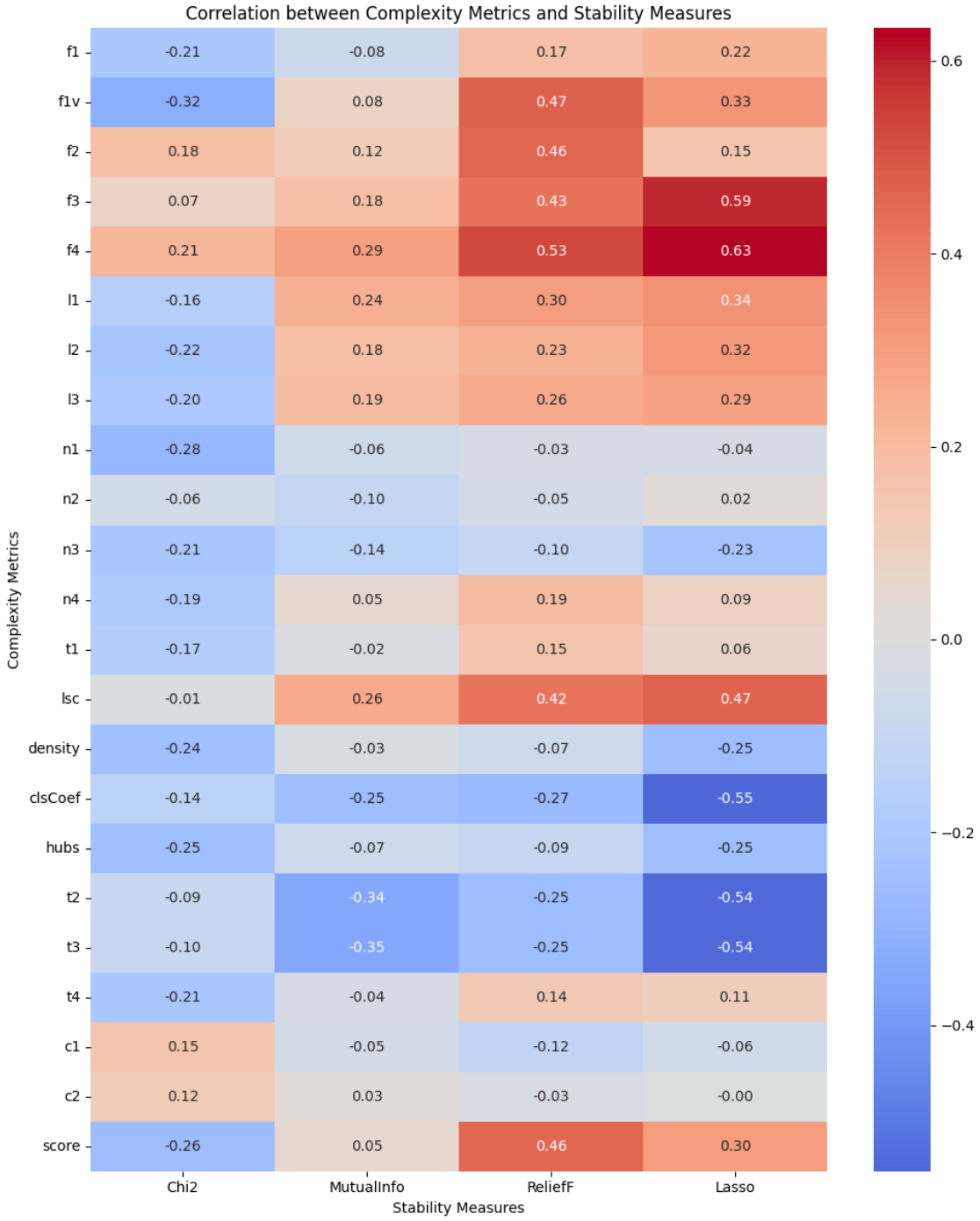
```
Merged dataset saved to: ../data/results/originaldata-
results/merged_complexity_and_stability.csv
```

0.7 Correlation between Complexity Metrics and Stability Measures

[35]:
```
# Analyzing Correlation Between Dataset Complexity Metrics and Feature␣
 ↪Selection Stability
import pandas as pd
import seaborn as sns
import matplotlib.pyplot as plt

# 1. Read the CSV file (adjust the file path as needed)
file_path = "../data/results/originaldata-results/
 ↪merged_complexity_and_stability.csv"
df = pd.read_csv(file_path)

# 2. Define complexity and stability columns
complexity_cols = ['f1', 'f1v', 'f2', 'f3', 'f4', 'l1', 'l2', 'l3',
                   'n1', 'n2', 'n3', 'n4', 't1', 'lsc', 'density',
                   'clsCoef', 'hubs', 't2', 't3', 't4', 'c1', 'c2', 'score']

stability_cols = ['Chi2', 'MutualInfo', 'ReliefF', 'Lasso']

# 3. Keep only relevant columns for analysis
sub_df = df[complexity_cols + stability_cols]

# 4. Compute Pearson correlation matrix between complexity metrics and each␣
 ↪stability method
correlation_df = sub_df[complexity_cols].corrwith(sub_df[stability_cols[0]])
for col in stability_cols[1:]:
    correlation_df = pd.concat([correlation_df, sub_df[complexity_cols].
 ↪corrwith(sub_df[col])], axis=1)

correlation_df.columns = stability_cols

# 5. Save the correlation results to CSV
output_path = "../data/results/originaldata-results/
 ↪correlation_complexity_vs_stability.csv"
correlation_df.round(3).to_csv(output_path)

# 6. Print the correlation table
print("Pearson Correlation Table (Complexity vs Stability):")
print(correlation_df.round(3))

# 7. Draw a heatmap to visualize the correlations
plt.figure(figsize=(10, 12))
sns.heatmap(correlation_df, annot=True, cmap='coolwarm', center=0, fmt=".2f")
plt.title("Correlation between Complexity Metrics and Stability Measures")
plt.ylabel("Complexity Metrics")
plt.xlabel("Stability Measures")
```

```
plt.tight_layout()
plt.show()
```

```
Pearson Correlation Table (Complexity vs Stability):
           Chi2  MutualInfo  ReliefF  Lasso
f1      -0.207      -0.077    0.174  0.224
f1v     -0.316       0.077    0.469  0.331
f2       0.178       0.120    0.462  0.151
f3       0.075       0.184    0.429  0.588
f4       0.213       0.293    0.531  0.634
l1      -0.158       0.240    0.296  0.340
l2      -0.219       0.179    0.232  0.315
l3      -0.199       0.193    0.261  0.289
n1      -0.282      -0.063   -0.034 -0.036
n2      -0.056      -0.103   -0.047  0.020
n3      -0.213      -0.144   -0.102 -0.227
n4      -0.188       0.050    0.189  0.086
t1      -0.168      -0.023    0.154  0.062
lsc     -0.007       0.263    0.421  0.465
density -0.243      -0.026   -0.065 -0.251
clsCoef -0.143      -0.252   -0.267 -0.551
hubs    -0.248      -0.066   -0.093 -0.247
t2      -0.090      -0.343   -0.253 -0.544
t3      -0.095      -0.347   -0.252 -0.542
t4      -0.209      -0.036    0.137  0.107
c1       0.153      -0.049   -0.123 -0.060
c2       0.123       0.025   -0.031 -0.002
score   -0.257       0.049    0.457  0.301
```


Correlation between Complexity Metrics and Stability Measures
Complexity Metrics
f1 -0.21 -0.08 0.17 0.22
f1v -0.32 0.08 0.47 0.33
f2 0.18 0.12 0.46 0.15
f3 0.07 0.18 0.43 0.59
f4 0.21 0.29 0.53 0.63
l1 -0.16 0.24 0.30 0.34
l2 -0.22 0.18 0.23 0.32
l3 -0.20 0.19 0.26 0.29
n1 -0.28 -0.06 -0.03 -0.04
n2 -0.06 -0.10 -0.05 0.02
n3 -0.21 -0.14 -0.10 -0.23
n4 -0.19 0.05 0.19 0.09
t1 -0.17 -0.02 0.15 0.06
lsc -0.01 0.26 0.42 0.47
density -0.24 -0.03 -0.07 -0.25
clsCoef -0.14 -0.25 -0.27 -0.55
hubs -0.25 -0.07 -0.09 -0.25
t2 -0.09 -0.34 -0.25 -0.54
t3 -0.10 -0.35 -0.25 -0.54
t4 -0.21 -0.04 0.14 0.11
c1 0.15 -0.05 -0.12 -0.06
c2 0.12 0.03 -0.03 -0.00
score -0.26 0.05 0.46 0.30
Chi2
MutualInfo
ReliefF
Lasso
Stability Measures
0.6
0.4
0.2
0.0
−0.2
−0.4

0.8 Feature Importance Mean with Random Forest

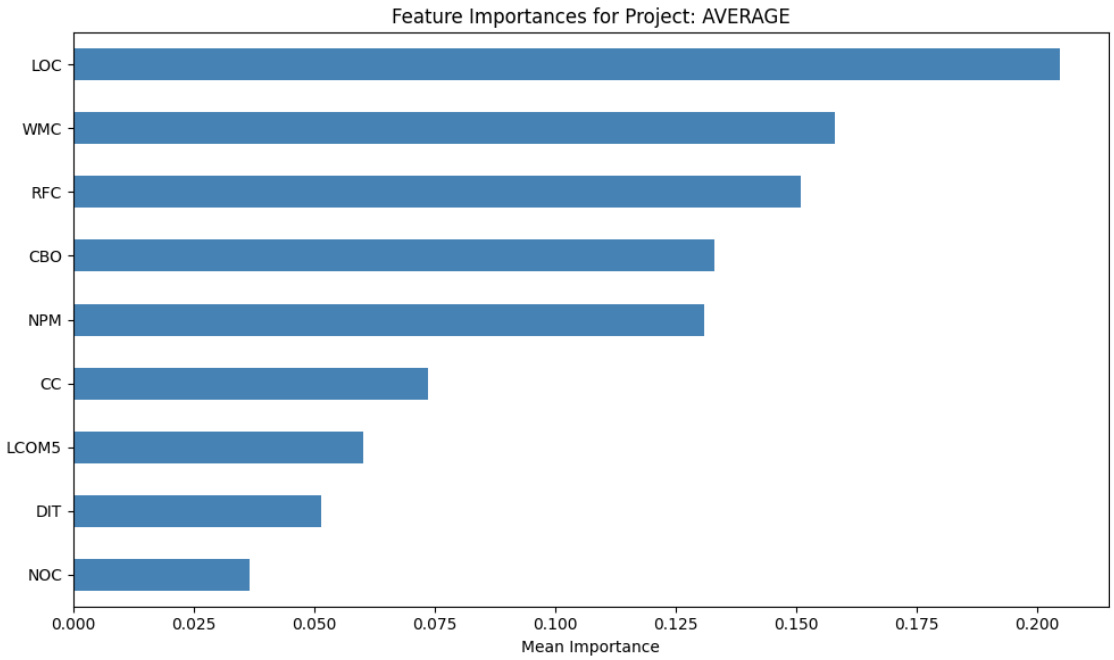
[14]:
```
import os
import numpy as np
import pandas as pd
from sklearn.ensemble import RandomForestClassifier
from sklearn.preprocessing import LabelEncoder
from sklearn.model_selection import StratifiedShuffleSplit

# Configuration
dataset_folder = "../data/original-datasets"  # Folder containing the datasets
output_csv_path = "../data/results/originaldata-results/
 ↪summary_feature_importance_mean.csv"
features = ['CC', 'LCOM5', 'WMC', 'CBO', 'RFC', 'DIT', 'NOC', 'LOC', 'NPM']
target = 'isExistBug'
n_iter = 30
random_state = None

# List to hold mean importances for all projects
importance_summary = []

# Loop through all project files
for filename in os.listdir(dataset_folder):
    if filename.endswith(".csv"):
        project_name = os.path.splitext(filename)[0]
        file_path = os.path.join(dataset_folder, filename)
        print(f"Processing: {project_name}")

        # Load dataset
        df = pd.read_csv(file_path)
        X = df[features]
        y = LabelEncoder().fit_transform(df[target])

        # Perform stratified sampling
        splitter = StratifiedShuffleSplit(n_splits=n_iter, test_size=0.3,␣
 ↪random_state=random_state)
        all_importances = []

        for train_idx, _ in splitter.split(X, y):
            X_train = X.iloc[train_idx]
            y_train = y[train_idx]

            rf = RandomForestClassifier(n_estimators=100,␣
 ↪random_state=random_state)
            rf.fit(X_train, y_train)
            all_importances.append(rf.feature_importances_)
```

```
        # Calculate mean importances
        mean_importance = np.mean(all_importances, axis=0)

        # Store results by project name
        row = {"project_name": project_name}
        for i, feat in enumerate(features):
            row[feat] = round(mean_importance[i], 6)

        importance_summary.append(row)

# Convert to DataFrame
df_result = pd.DataFrame(importance_summary)
df_result = df_result[["project_name"] + features]

# Save to CSV
os.makedirs(os.path.dirname(output_csv_path), exist_ok=True)
df_result.to_csv(output_csv_path, index=False)

print("\nImportance mean summary saved to:", output_csv_path)
```

```
Processing: BugPrediction_Eclipse
Processing: BugPrediction_Equinox
Processing: BugPrediction_lucene
Processing: BugPrediction_Mylyn
Processing: BugPrediction_PDE
Processing: Github_Android
Processing: Github_antlr4
Processing: Github_BroadleafCommerce
Processing: Github_ceylon
Processing: Github_Elasticsearch
Processing: Github_hazelcast
Processing: Github_JUnit
Processing: Github_mapdb
Processing: Github_mcMMO
Processing: Github_mct17
Processing: Github_Neo4j
Processing: Github_Netty
Processing: Github_orientdb
Processing: Github_oryx
Processing: Github_titan
Processing: Promise_ant14
Processing: Promise_camel16
Processing: Promise_ckjm18
Processing: Promise_forrest08
Processing: Promise_ivy20
Processing: Promise_jedit43
Processing: Promise_log4j
Processing: Promise_lucene24
```

```
Processing: Promise_pbeans2
Processing: Promise_poi30
Processing: Promise_synapse12
Processing: Promise_velocity16
Processing: Promise_xalan27
Processing: Promise_xerces

Importance mean summary saved to: ../data/results/originaldata-
results/summary_feature_importance_mean.csv
```

[26]:
```python
import pandas as pd
import matplotlib.pyplot as plt

# Path to the CSV file
file_path = "../data/results/originaldata-results/
 ↪summary_feature_importance_mean.csv"

# Read the CSV file into a DataFrame
df = pd.read_csv(file_path)

# Set 'project_name' column as the index
df.set_index("project_name", inplace=True)

# Specify the project to visualize (e.g., use "AVERAGE" for average importances)
project_name = "AVERAGE"  # Replace with any project name you want to visualize
importance_values = df.loc[project_name].sort_values()

# Plot horizontal bar chart
plt.figure(figsize=(10, 6))
importance_values.plot(kind='barh', color='steelblue')
plt.xlabel("Mean Importance")
plt.title(f"Feature Importances for Project: {project_name}")
plt.tight_layout()
plt.show()
```



[28]:
```
## Selected Features: LOC, WMC, RFC, CBO, NPM
```

0.9 Filtered Dataset

[15]:
```
import pandas as pd
import os

# Folder path
dataset_path = '../data/filtered-datasets'

# Required columns
required_columns = ['WMC', 'CBO', 'RFC', 'LOC', 'NPM', 'isExistBug']

# List to collect all valid DataFrames
df_list = []

# Iterate through all CSV files in the folder
for filename in os.listdir(dataset_path):
    if filename.endswith('.csv'):
        file_path = os.path.join(dataset_path, filename)
        try:
            df = pd.read_csv(file_path)

            # Check if all required columns are present
            if all(col in df.columns for col in required_columns):
```

```
                # Extract project name from the filename (without extension)
                project_name = os.path.splitext(filename)[0]
                df = df[required_columns].copy()  # Keep only required columns
                df['project'] = project_name      # Add project name as a column
                df_list.append(df)
            else:
                print(f"Missing required columns: {filename}")
        except Exception as e:
            print(f"Error while reading file: {filename} | {e}")

# If at least one file was loaded successfully, concatenate them
if df_list:
    combined_df = pd.concat(df_list, ignore_index=True)
    print(f"Total number of rows: {len(combined_df)}")
    print(combined_df.head())
else:
    print("No valid file found. Please check the files and column names.")
```

```
Total number of rows: 37630
   WMC  CBO  RFC  LOC  NPM  isExistBug                project
0   18    4   20  243   13           0  BugPrediction_Eclipse
1    5    1    5   71    5           0  BugPrediction_Eclipse
2   16    6   11   59    3           0  BugPrediction_Eclipse
3   14    3   11  308   10           0  BugPrediction_Eclipse
4    2    0    2   27    2           0  BugPrediction_Eclipse
```

0.10 Computation Dataset Complexity Metrics

[16]:
```
# Batch Computation and Export of Dataset Complexity Metrics for Multiple␣
↪Projects

import os
import pandas as pd
from problexity import ComplexityCalculator
from sklearn.preprocessing import LabelEncoder

# Input and output folder paths
input_folder = "../data/filtered-datasets/"
output_folder = "../data/filtereddata-complexitymetrics/"

# Create output folder if it doesn't exist
os.makedirs(output_folder, exist_ok=True)

# Get all project names by removing .csv extension
project_names = [
    os.path.splitext(filename)[0]
    for filename in os.listdir(input_folder)
```

```
    if filename.endswith(".csv")
]

# Process each project
for project_name in project_names:
    input_file = os.path.join(input_folder, f"{project_name}.csv")
    output_file = os.path.join(output_folder, f"CM_{project_name}.csv")

    if not os.path.exists(output_file):
        print(f"Calculating metrics for {project_name}...")

        try:
            # Read dataset
            df = pd.read_csv(input_file)

            # Separate features and target
            X = df.drop(columns=["isExistBug"]).astype(float)
            y = LabelEncoder().fit_transform(df["isExistBug"])

            # Compute complexity metrics
            cc = ComplexityCalculator()
            cc.fit(X, y)
            report = cc.report()
            metrics = report["complexities"]
            metrics["score"] = report["score"]

            # Convert to DataFrame
            df_metrics = pd.DataFrame([metrics])
            df_metrics.insert(0, "project_name", project_name)

            # Save to CSV
            df_metrics.to_csv(output_file, index=False)
            print(f"{output_file} created successfully.")

        except Exception as e:
            print(f"Error processing {project_name}: {e}")

    else:
        print(f"{output_file} already exists. Skipping.")
```

```
Calculating metrics for BugPrediction_Eclipse…
../data/filtereddata-complexitymetrics/CM_BugPrediction_Eclipse.csv created
successfully.
Calculating metrics for BugPrediction_Equinox…
../data/filtereddata-complexitymetrics/CM_BugPrediction_Equinox.csv created
successfully.
Calculating metrics for BugPrediction_lucene…
```

```
../data/filtereddata-complexitymetrics/CM_BugPrediction_lucene.csv created
successfully.
Calculating metrics for BugPrediction_Mylyn…
../data/filtereddata-complexitymetrics/CM_BugPrediction_Mylyn.csv created
successfully.
Calculating metrics for BugPrediction_PDE…
../data/filtereddata-complexitymetrics/CM_BugPrediction_PDE.csv created
successfully.
Calculating metrics for Github_Android…
../data/filtereddata-complexitymetrics/CM_Github_Android.csv created
successfully.
Calculating metrics for Github_antlr4…
../data/filtereddata-complexitymetrics/CM_Github_antlr4.csv created
successfully.
Calculating metrics for Github_BroadleafCommerce…
../data/filtereddata-complexitymetrics/CM_Github_BroadleafCommerce.csv created
successfully.
Calculating metrics for Github_ceylon…
../data/filtereddata-complexitymetrics/CM_Github_ceylon.csv created
successfully.
Calculating metrics for Github_Elasticsearch…
../data/filtereddata-complexitymetrics/CM_Github_Elasticsearch.csv created
successfully.
Calculating metrics for Github_hazelcast…
../data/filtereddata-complexitymetrics/CM_Github_hazelcast.csv created
successfully.
Calculating metrics for Github_JUnit…
../data/filtereddata-complexitymetrics/CM_Github_JUnit.csv created successfully.
Calculating metrics for Github_mapdb…
../data/filtereddata-complexitymetrics/CM_Github_mapdb.csv created successfully.
Calculating metrics for Github_mcMMO…
../data/filtereddata-complexitymetrics/CM_Github_mcMMO.csv created successfully.
Calculating metrics for Github_mct17…
../data/filtereddata-complexitymetrics/CM_Github_mct17.csv created successfully.
Calculating metrics for Github_Neo4j…
../data/filtereddata-complexitymetrics/CM_Github_Neo4j.csv created successfully.
Calculating metrics for Github_Netty…
../data/filtereddata-complexitymetrics/CM_Github_Netty.csv created successfully.
Calculating metrics for Github_orientdb…
../data/filtereddata-complexitymetrics/CM_Github_orientdb.csv created
successfully.
Calculating metrics for Github_oryx…
../data/filtereddata-complexitymetrics/CM_Github_oryx.csv created successfully.
Calculating metrics for Github_titan…
../data/filtereddata-complexitymetrics/CM_Github_titan.csv created successfully.
Calculating metrics for Promise_ant14…
../data/filtereddata-complexitymetrics/CM_Promise_ant14.csv created
successfully.
```

```
Calculating metrics for Promise_camel16…
../data/filtereddata-complexitymetrics/CM_Promise_camel16.csv created
successfully.
Calculating metrics for Promise_ckjm18…
../data/filtereddata-complexitymetrics/CM_Promise_ckjm18.csv created
successfully.
Calculating metrics for Promise_forrest08…
../data/filtereddata-complexitymetrics/CM_Promise_forrest08.csv created
successfully.
Calculating metrics for Promise_ivy20…
../data/filtereddata-complexitymetrics/CM_Promise_ivy20.csv created
successfully.
Calculating metrics for Promise_jedit43…
../data/filtereddata-complexitymetrics/CM_Promise_jedit43.csv created
successfully.
Calculating metrics for Promise_log4j…
../data/filtereddata-complexitymetrics/CM_Promise_log4j.csv created
successfully.
Calculating metrics for Promise_lucene24…
../data/filtereddata-complexitymetrics/CM_Promise_lucene24.csv created
successfully.
Calculating metrics for Promise_pbeans2…
../data/filtereddata-complexitymetrics/CM_Promise_pbeans2.csv created
successfully.
Calculating metrics for Promise_poi30…
../data/filtereddata-complexitymetrics/CM_Promise_poi30.csv created
successfully.
Calculating metrics for Promise_synapse12…
../data/filtereddata-complexitymetrics/CM_Promise_synapse12.csv created
successfully.
Calculating metrics for Promise_velocity16…
../data/filtereddata-complexitymetrics/CM_Promise_velocity16.csv created
successfully.
Calculating metrics for Promise_xalan27…
../data/filtereddata-complexitymetrics/CM_Promise_xalan27.csv created
successfully.
Calculating metrics for Promise_xerces…
../data/filtereddata-complexitymetrics/CM_Promise_xerces.csv created
successfully.
```

0.11 Merge Complexity Metrics

[17]:
```python
# Merging Project-Level Complexity Metric Files into a Single CSV
import os
import pandas as pd

# Input folder and output file path
```

```
input_folder = "../data/filtereddata-complexitymetrics/"
output_folder = "../data/results/filtereddata-results/"
output_file = os.path.join(output_folder, "merged_complexity_metrics.csv")

# Create output folder if it doesn't exist
os.makedirs(output_folder, exist_ok=True)

# Initialize an empty list
df_list = []

# Read all CSV files in the input folder that start with "CM_"
for filename in os.listdir(input_folder):
    if filename.startswith("CM_") and filename.endswith(".csv"):
        filepath = os.path.join(input_folder, filename)
        df = pd.read_csv(filepath)
        df_list.append(df)

# Concatenate all dataframes
merged_df = pd.concat(df_list, ignore_index=True)

# Save the merged dataframe to CSV
merged_df.to_csv(output_file, index=False)
print(f"All complexity metrics merged into: {output_file}")
```

```
All complexity metrics merged into: ../data/results/filtereddata-
results/merged_complexity_metrics.csv
```

0.12 Feature Selection Stability Metrics

[19]:
```
# Automated Feature Selection and Stability Evaluation Across Multiple Projects
import os
import sys
import numpy as np
import pandas as pd
from sklearn.preprocessing import LabelEncoder
from sklearn.feature_selection import SelectKBest, chi2, mutual_info_classif
from sklearn.linear_model import LogisticRegression
from skrebate import ReliefF
from sklearn.model_selection import StratifiedShuffleSplit
import random

# Add 'stability' module to path
sys.path.append(os.path.abspath('stability'))
import stability as st

# Folder configuration
dataset_folder = "../data/filtered-datasets"
```

```
output_dir = "../data/filtereddata-fs-stability-metrics"
os.makedirs(output_dir, exist_ok=True)

# Feature and target definitions
features = ['WMC', 'CBO', 'RFC', 'LOC', 'NPM']
target = 'isExistBug'

# Feature selection parameters
k = 2
n_iter = 30
random_state = None

# Helper function: convert feature selection results to binary matrix
def fs_result_to_binary_matrix(fs_result_list, all_features):
    return np.array([[1 if feat in selected else 0 for feat in all_features]␣
 ↪for selected in fs_result_list])

# Process each CSV file
for filename in os.listdir(dataset_folder):
    if filename.endswith(".csv"):
        project_name = os.path.splitext(filename)[0]
        file_path = os.path.join(dataset_folder, filename)

        print(f"\nProcessing project: {project_name}")

        # 1. Load dataset
        df = pd.read_csv(file_path)
        X = df[features]
        y = LabelEncoder().fit_transform(df[target])

        splitter = StratifiedShuffleSplit(n_splits=n_iter, test_size=0.3,␣
 ↪random_state=random_state)
        fs_results = {method: [] for method in ["Chi2", "MutualInfo",␣
 ↪"ReliefF", "Lasso"]}

        # 2. Perform feature selection
        for _, (train_idx, _) in enumerate(splitter.split(X, y), start=1):
            X_sample = X.iloc[train_idx]
            y_sample = y[train_idx]

            # Chi2
            chi2_selector = SelectKBest(score_func=chi2, k=k)
            chi2_selector.fit(X_sample, y_sample)
            fs_results["Chi2"].append(X_sample.columns[chi2_selector.
 ↪get_support()].tolist())

            # Mutual Info
```

```
            mi_selector = SelectKBest(score_func=mutual_info_classif, k=k)
            mi_selector.fit(X_sample, y_sample)
            fs_results["MutualInfo"].append(X_sample.columns[mi_selector.
↪get_support()].tolist())

            # ReliefF
            relief_selector = ReliefF(n_features_to_select=k)
            relief_selector.fit(X_sample.values.astype(float), y_sample)
            top_relief = relief_selector.top_features_[:k]
            fs_results["ReliefF"].append(X_sample.columns[top_relief].tolist())

            # Lasso
            lasso_model = LogisticRegression(penalty='l1', solver='liblinear',␣
↪random_state=random.randint(0, 9999))
            lasso_model.fit(X_sample, y_sample)
            lasso_features = X_sample.columns[lasso_model.coef_[0] != 0].
↪tolist()
            fs_results["Lasso"].append(lasso_features[:k] if␣
↪len(lasso_features) > k else lasso_features)

        # 3. Save selected features to CSV (if not already exists)
        for method, results in fs_results.items():
            out_path = f"{output_dir}/{project_name}_{method}_selected_features.
↪csv"
            if not os.path.exists(out_path):
                df_method = pd.DataFrame(results)
                df_method.index = [f"Run_{i+1}" for i in range(n_iter)]
                df_method.columns = [f"Feature_{j+1}" for j in range(df_method.
↪shape[1])]
                df_method.insert(0, "Project", project_name)
                df_method.to_csv(out_path, index_label="Run")
            else:
                print(f"Skipped existing file: {out_path}")

        # 4. Compute stability scores and save to CSV (if not already exists)
        stab_path = f"{output_dir}/{project_name}_feature_selection_stability.
↪csv"
        if not os.path.exists(stab_path):
            stability_records = []
            for method in fs_results:
                Z = fs_result_to_binary_matrix(fs_results[method], features)
                stab = st.getVarianceofStability(Z)
                ci = st.confidenceIntervals(Z)
                stability_records.append({
                    "Project": project_name,
                    "Method": method,
```

```
                    "Stability": round(stab['stability'], 4),
                    "CI_Lower": round(ci['lower'], 4),
                    "CI_Upper": round(ci['upper'], 4)
                })
            df_stability = pd.DataFrame(stability_records)
            df_stability.to_csv(stab_path, index=False)
        else:
            print(f"Skipped existing stability file: {stab_path}")

print("\nAll projects processed. Feature selection results and stability scores␣
 ↪are saved.")
```

```
Processing project: BugPrediction_Eclipse

Processing project: BugPrediction_Equinox

Processing project: BugPrediction_lucene

Processing project: BugPrediction_Mylyn

Processing project: BugPrediction_PDE

Processing project: Github_Android

Processing project: Github_antlr4

Processing project: Github_BroadleafCommerce

Processing project: Github_ceylon

Processing project: Github_Elasticsearch

Processing project: Github_hazelcast

Processing project: Github_JUnit

Processing project: Github_mapdb
C:\Users\ramaz\AppData\Roaming\Python\Python313\site-
packages\sklearn\svm\_base.py:1249: ConvergenceWarning: Liblinear failed to
converge, increase the number of iterations.
  warnings.warn(
C:\Users\ramaz\AppData\Roaming\Python\Python313\site-
packages\sklearn\svm\_base.py:1249: ConvergenceWarning: Liblinear failed to
converge, increase the number of iterations.
  warnings.warn(
```

```
Processing project: Github_mcMMO

Processing project: Github_mct17

Processing project: Github_Neo4j

Processing project: Github_Netty

Processing project: Github_orientdb

Processing project: Github_oryx

Processing project: Github_titan

Processing project: Promise_ant14

Processing project: Promise_camel16

Processing project: Promise_ckjm18
C:\Users\ramaz\AppData\Roaming\Python\Python313\site-
packages\sklearn\svm\_base.py:1249: ConvergenceWarning: Liblinear failed to
converge, increase the number of iterations.
  warnings.warn(
C:\Users\ramaz\AppData\Roaming\Python\Python313\site-
packages\sklearn\svm\_base.py:1249: ConvergenceWarning: Liblinear failed to
converge, increase the number of iterations.
  warnings.warn(


Processing project: Promise_forrest08

Processing project: Promise_ivy20

Processing project: Promise_jedit43

Processing project: Promise_log4j

Processing project: Promise_lucene24

Processing project: Promise_pbeans2
C:\Users\ramaz\AppData\Roaming\Python\Python313\site-
packages\sklearn\svm\_base.py:1249: ConvergenceWarning: Liblinear failed to
converge, increase the number of iterations.
  warnings.warn(


Processing project: Promise_poi30
```

```
Processing project: Promise_synapse12

Processing project: Promise_velocity16

Processing project: Promise_xalan27

C:\Users\ramaz\AppData\Roaming\Python\Python313\site-
packages\sklearn\svm\_base.py:1249: ConvergenceWarning: Liblinear failed to
converge, increase the number of iterations.
  warnings.warn(
C:\Users\ramaz\AppData\Roaming\Python\Python313\site-
packages\sklearn\svm\_base.py:1249: ConvergenceWarning: Liblinear failed to
converge, increase the number of iterations.
  warnings.warn(
C:\Users\ramaz\AppData\Roaming\Python\Python313\site-
packages\sklearn\svm\_base.py:1249: ConvergenceWarning: Liblinear failed to
converge, increase the number of iterations.
  warnings.warn(


Processing project: Promise_xerces

All projects processed. Feature selection results and stability scores are
saved.
```

0.13 Merge Feature Selection Stability Metrics

[20]:
```python
# Merging and Pivoting Feature Selection Stability Reports with Custom Project␣
 ↪Order
import os
import pandas as pd

# Input and output folders
input_folder = "../data/filtereddata-fs-stability-metrics"
output_folder = "../data/results/filtereddata-results"
os.makedirs(output_folder, exist_ok=True)

# Custom project order (defined manually)
custom_order = [
    "BugPrediction_Eclipse", "BugPrediction_Equinox", "BugPrediction_lucene",␣
 ↪"BugPrediction_Mylyn",
    "BugPrediction_PDE", "Github_Android", "Github_antlr4",␣
 ↪"Github_BroadleafCommerce", "Github_ceylon",
    "Github_Elasticsearch", "Github_hazelcast", "Github_JUnit", "Github_mapdb",␣
 ↪"Github_mcMMO",
    "Github_mct17", "Github_Neo4j", "Github_Netty", "Github_orientdb",␣
 ↪"Github_oryx", "Github_titan",
```

```
    "Promise_ant14", "Promise_camel16", "Promise_ckjm18", "Promise_forrest08",␣
 ↪"Promise_ivy20",
    "Promise_jedit43", "Promise_log4j", "Promise_lucene24", "Promise_pbeans2",␣
 ↪"Promise_poi30",
    "Promise_synapse12", "Promise_velocity16", "Promise_xalan27",␣
 ↪"Promise_xerces"
]

# Read and merge all CSV files
df_list = []
for filename in sorted(os.listdir(input_folder)):
    if filename.endswith("_feature_selection_stability.csv"):
        file_path = os.path.join(input_folder, filename)
        df = pd.read_csv(file_path)
        df_list.append(df)

merged_df = pd.concat(df_list, ignore_index=True)

# Keep only needed columns
merged_df = merged_df[["Project", "Method", "Stability"]]

# Pivot: each method becomes a column
pivot_df = merged_df.pivot(index="Project", columns="Method",␣
 ↪values="Stability").reset_index()

# Reorder method columns if needed
desired_order = ["Project", "Chi2", "MutualInfo", "ReliefF", "Lasso"]
pivot_df = pivot_df[desired_order]

# Sort rows by custom project order
pivot_df["Project"] = pd.Categorical(pivot_df["Project"],␣
 ↪categories=custom_order, ordered=True)
pivot_df = pivot_df.sort_values("Project").reset_index(drop=True)

# Save result
output_path = os.path.join(output_folder, "merged_feature_selection_stability.
 ↪csv")
pivot_df.to_csv(output_path, index=False)

print(f"Merged and ordered stability matrix saved to: {output_path}")
```

```
Merged and ordered stability matrix saved to: ../data/results/filtereddata-
results\merged_feature_selection_stability.csv
```

0.14 Merge Complexity Metrics and Stability Measures

[21]:
```
import pandas as pd

# Load both CSV files
complexity_path = "../data/results/filtereddata-results/
 ↪merged_complexity_metrics.csv"
stability_path = "../data/results/filtereddata-results/
 ↪merged_feature_selection_stability.csv"

df_complexity = pd.read_csv(complexity_path)
df_stability = pd.read_csv(stability_path)

# Rename 'Project' column in stability to match 'project_name'
df_stability = df_stability.rename(columns={"Project": "project_name"})

# Merge on project_name
merged_df = pd.merge(df_complexity, df_stability, on="project_name",␣
 ↪how="inner")

# Save to CSV
merged_output_path = "../data/results/filtereddata-results/
 ↪merged_complexity_and_stability.csv"
merged_df.to_csv(merged_output_path, index=False)

print("Merged dataset saved to:", merged_output_path)
```

```
Merged dataset saved to: ../data/results/filtereddata-
results/merged_complexity_and_stability.csv
```

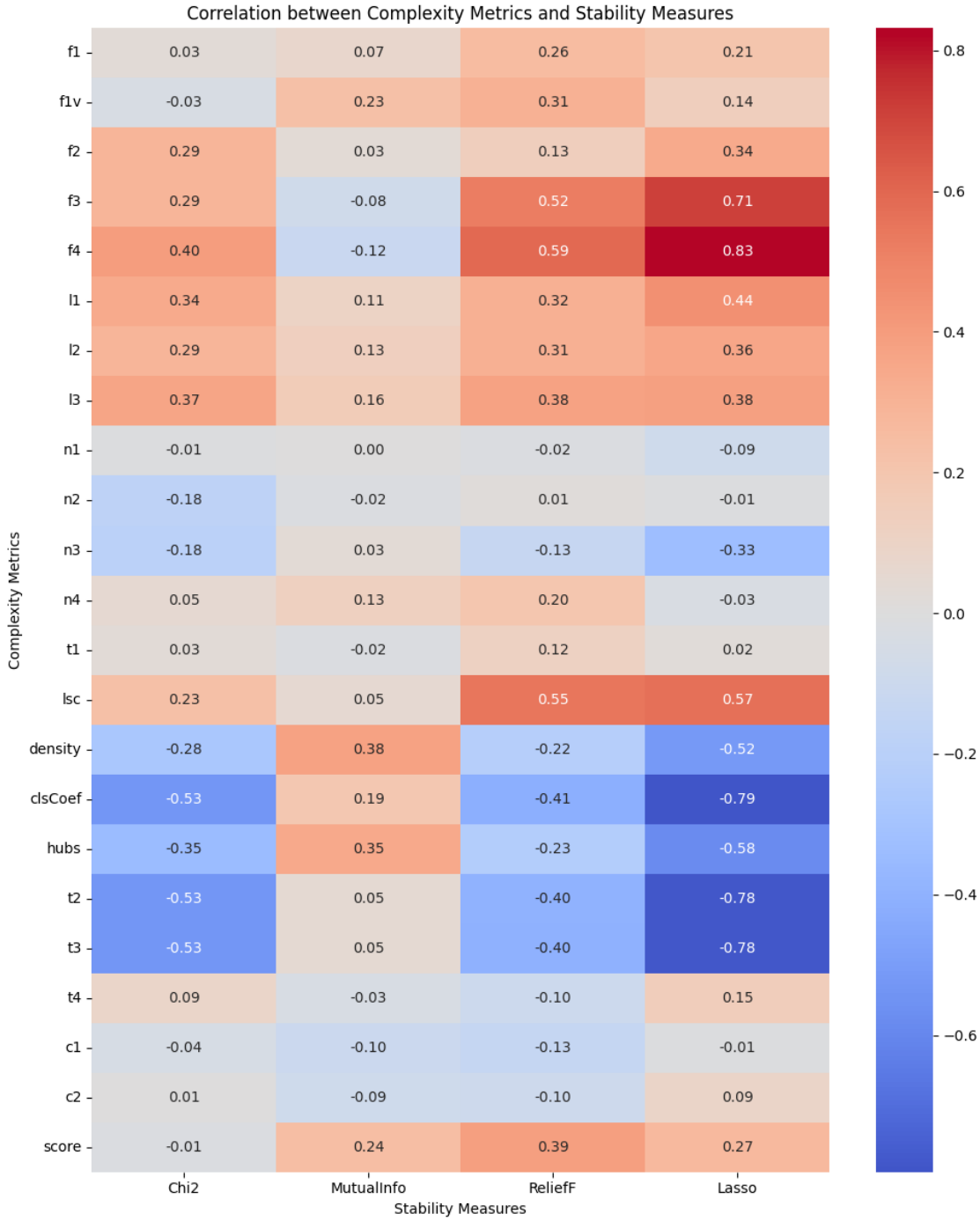
0.15 Correlation between Complexity Metrics and Stability Measures

[30]:
```
# Analyzing Correlation Between Dataset Complexity Metrics and Feature␣
 ↪Selection Stability
import pandas as pd
import seaborn as sns
import matplotlib.pyplot as plt

# 1. Read the CSV file (update the path according to your system)
file_path = "../data/results/filtereddata-results/
 ↪merged_complexity_and_stability.csv"
df = pd.read_csv(file_path)

# 2. Define complexity and stability columns
complexity_cols = ['f1', 'f1v', 'f2', 'f3', 'f4', 'l1', 'l2', 'l3',
                   'n1', 'n2', 'n3', 'n4', 't1', 'lsc', 'density',
                   'clsCoef', 'hubs', 't2', 't3', 't4', 'c1', 'c2', 'score']
```

```python
stability_cols = ['Chi2', 'MutualInfo', 'ReliefF', 'Lasso']

# 3. Extract only the required columns
sub_df = df[complexity_cols + stability_cols]

# 4. Compute the correlation matrix between complexity and stability measures
correlation_df = sub_df[complexity_cols].corrwith(sub_df[stability_cols[0]])
for col in stability_cols[1:]:
    correlation_df = pd.concat([correlation_df, sub_df[complexity_cols].
 ↪corrwith(sub_df[col])], axis=1)

correlation_df.columns = stability_cols

# 5. Print the Pearson correlation table
print("Pearson Correlation Table (Complexity vs Stability):")
print(correlation_df.round(3))

# 6. Draw the heatmap
plt.figure(figsize=(10, 12))
sns.heatmap(correlation_df, annot=True, cmap='coolwarm', center=0, fmt=".2f")
plt.title("Correlation between Complexity Metrics and Stability Measures")
plt.ylabel("Complexity Metrics")
plt.xlabel("Stability Measures")
plt.tight_layout()
plt.show()
```

```
Pearson Correlation Table (Complexity vs Stability):
          Chi2  MutualInfo  ReliefF  Lasso
f1       0.030       0.074    0.257  0.208
f1v     -0.034       0.232    0.308  0.139
f2       0.287       0.034    0.134  0.339
f3       0.291      -0.077    0.523  0.713
f4       0.400      -0.120    0.592  0.832
l1       0.341       0.106    0.317  0.445
l2       0.288       0.129    0.313  0.356
l3       0.368       0.164    0.377  0.381
n1      -0.007       0.005   -0.016 -0.088
n2      -0.177      -0.016    0.014 -0.012
n3      -0.185       0.035   -0.129 -0.333
n4       0.053       0.126    0.198 -0.028
t1       0.026      -0.020    0.117  0.020
lsc      0.228       0.051    0.550  0.568
density -0.279       0.380   -0.222 -0.516
clsCoef -0.533       0.194   -0.414 -0.794
hubs    -0.349       0.348   -0.232 -0.585
t2      -0.530       0.047   -0.400 -0.784
t3      -0.529       0.046   -0.404 -0.783
```

t4	0.088	-0.034	-0.102	0.148
c1	-0.044	-0.104	-0.134	-0.008
c2	0.006	-0.086	-0.095	0.093
score	-0.014	0.243	0.390	0.267

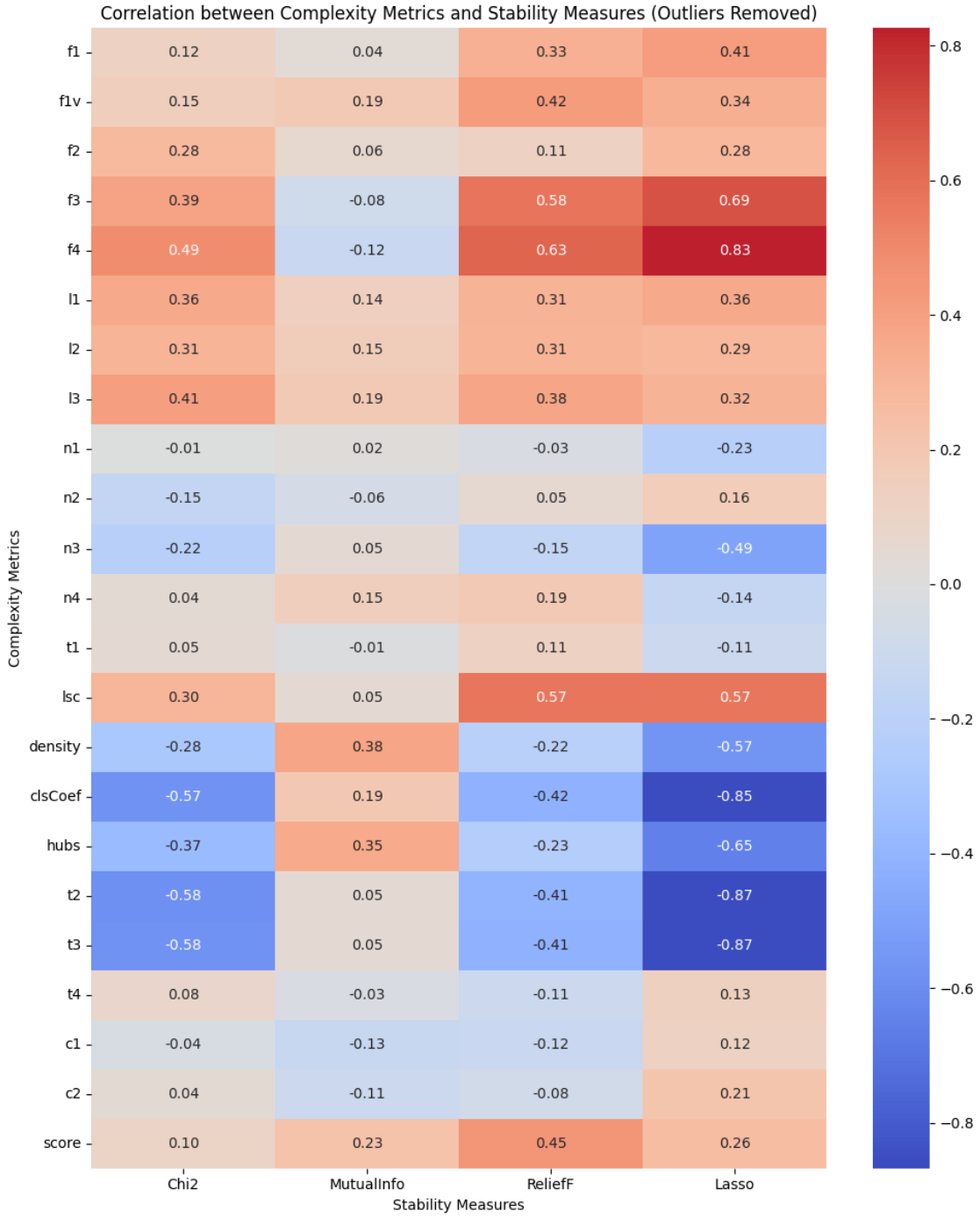


0.16 Correlation between Complexity Metrics and Stability Measures After Outlier Projects

[34]:
```
# Analyzing Correlation Between Dataset Complexity Metrics and Feature␣
 ↪Selection Stability
import pandas as pd
import seaborn as sns
import matplotlib.pyplot as plt

# 1. Read the CSV file (update the file path to match your environment)
file_path = "../data/results/filtereddata-results/
 ↪merged_complexity_and_stability.csv"
df = pd.read_csv(file_path)

# 2. Remove outlier projects based on previously detected extreme bug rates
outliers = ["Promise_xalan27", "Promise_log4j"]
df = df[~df["project_name"].isin(outliers)]

# 3. Define the columns for complexity metrics and stability scores
complexity_cols = ['f1', 'f1v', 'f2', 'f3', 'f4', 'l1', 'l2', 'l3',
                   'n1', 'n2', 'n3', 'n4', 't1', 'lsc', 'density',
                   'clsCoef', 'hubs', 't2', 't3', 't4', 'c1', 'c2', 'score']

stability_cols = ['Chi2', 'MutualInfo', 'ReliefF', 'Lasso']

# 4. Keep only the relevant columns for correlation analysis
sub_df = df[complexity_cols + stability_cols]

# 5. Compute the Pearson correlation between complexity metrics and each␣
 ↪stability method
correlation_df = sub_df[complexity_cols].corrwith(sub_df[stability_cols[0]])
for col in stability_cols[1:]:
    correlation_df = pd.concat([correlation_df, sub_df[complexity_cols].
 ↪corrwith(sub_df[col])], axis=1)

correlation_df.columns = stability_cols

# 6. Save the correlation results to CSV
output_path = "../data/results/filtereddata-results/
 ↪correlation_complexity_vs_stability.csv"
correlation_df.round(3).to_csv(output_path)

# 7. Print the resulting correlation table
print("Pearson Correlation Table (Outliers Removed):")
print(correlation_df.round(3))

# 8. Draw a heatmap to visualize the correlations
```

```
plt.figure(figsize=(10, 12))
sns.heatmap(correlation_df, annot=True, cmap='coolwarm', center=0, fmt=".2f")
plt.title("Correlation between Complexity Metrics and Stability Measures␣
  ↪(Outliers Removed)")
plt.ylabel("Complexity Metrics")
plt.xlabel("Stability Measures")
plt.tight_layout()
plt.show()
```

```
Pearson Correlation Table (Outliers Removed):
           Chi2  MutualInfo  ReliefF  Lasso
f1        0.121       0.037    0.326  0.411
f1v       0.146       0.185    0.420  0.336
f2        0.275       0.060    0.114  0.285
f3        0.389      -0.080    0.576  0.693
f4        0.487      -0.121    0.630  0.826
l1        0.361       0.144    0.313  0.362
l2        0.309       0.153    0.310  0.290
l3        0.407       0.190    0.379  0.316
n1       -0.005       0.017   -0.033 -0.225
n2       -0.149      -0.056    0.055  0.161
n3       -0.220       0.052   -0.154 -0.494
n4        0.044       0.150    0.189 -0.144
t1        0.046      -0.012    0.114 -0.109
lsc       0.300       0.046    0.575  0.568
density  -0.279       0.379   -0.219 -0.567
clsCoef  -0.573       0.192   -0.416 -0.855
hubs     -0.366       0.351   -0.233 -0.652
t2       -0.584       0.051   -0.408 -0.868
t3       -0.582       0.049   -0.412 -0.867
t4        0.083      -0.028   -0.110  0.135
c1       -0.038      -0.130   -0.123  0.124
c2        0.039      -0.112   -0.077  0.214
score     0.101       0.230    0.445  0.259
```


Correlation between Complexity Metrics and Stability Measures (Outliers Removed)
Complexity Metrics
f1 0.12 0.04 0.33 0.41
f1v 0.15 0.19 0.42 0.34
f2 0.28 0.06 0.11 0.28
f3 0.39 -0.08 0.58 0.69
f4 0.49 -0.12 0.63 0.83
l1 0.36 0.14 0.31 0.36
l2 0.31 0.15 0.31 0.29
l3 0.41 0.19 0.38 0.32
n1 -0.01 0.02 -0.03 -0.23
n2 -0.15 -0.06 0.05 0.16
n3 -0.22 0.05 -0.15 -0.49
n4 0.04 0.15 0.19 -0.14
t1 0.05 -0.01 0.11 -0.11
lsc 0.30 0.05 0.57 0.57
density -0.28 0.38 -0.22 -0.57
clsCoef -0.57 0.19 -0.42 -0.85
hubs -0.37 0.35 -0.23 -0.65
t2 -0.58 0.05 -0.41 -0.87
t3 -0.58 0.05 -0.41 -0.87
t4 0.08 -0.03 -0.11 0.13
c1 -0.04 -0.13 -0.12 0.12
c2 0.04 -0.11 -0.08 0.21
score 0.10 0.23 0.45 0.26
Chi2
MutualInfo
ReliefF
Lasso
Stability Measures
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
−0.8