

Project Fake Finder - Progress Report 2

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Project Progress Report # 1

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1 Data Exploratory Data Analysis (EDA)

1.1 Environment Setup for EDA

Before we start our Exploratory Data Analysis, there are some additional packages we will need to install.

- kagglehub - Import our Kaggle dataset
- textstat - To gain additional insight with our text fields

```
[2]: %%capture
!pip install kagglehub > /dev/null 2>&1
!pip install textstat
```

1.1.1 Purpose:

Additionally, we want to update some of the default pandas options and set basic logging configuration to get a better view of our dataset during our data exploration.

```
[1]: import os
import logging
from typing import List
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
from pathlib import Path

# Set up logging for debug information:
logging.basicConfig(level=logging.INFO, format='%(levelname)s: %(message)s')

# Option 1: Set display options to show all rows:
```

```

pd.set_option('display.max_rows', None)

# Option 2: Set display options to show all columns:
pd.set_option('display.max_columns', None)

# Option 3: Set the width to show all content:
pd.set_option('display.width', None)

# Option 4: Set the max column width to avoid truncating cell contents:
pd.set_option('display.max_colwidth', None)

```

1.2 Data Wrangling

1.2.1 Step 1: Discovering

Discovery, also called data exploration, familiarizes the data scientist with source data in preparation for subsequent steps.

```

[4]: import kagglehub
import os
import pandas as pd

# Download latest version of the dataset
path = kagglehub.dataset_download("rishantenis/
↳real-and-fake-jobs-posting-prediction")
csv_file = [f for f in os.listdir(path) if f.endswith('.csv')][0]
df = pd.read_csv(os.path.join(path, csv_file))

```

```

-----
ModuleNotFoundError                                Traceback (most recent call last)
Input In [4], in <cell line: 1>()
----> 1 import kagglehub
      2 import os
      3 import pandas as pd

ModuleNotFoundError: No module named 'kagglehub'

```

Purpose: Get the first 5 rows of our dataset to make sure it loaded correctly and that there are no issues. Since the text columns has a lot of data we view those separately in an additional code cell.

```

[ ]: df[
    ['job_id',
     'title',
     'location',
     'department',
     'salary_range',

```

```

'telecommuting',
'has_company_logo',
'has_questions',
'employment_type',
'required_experience',
'required_education',
'industry',
'function',
'fraudulent'
]
].head()

```

```

[ ]:  job_id          title          location \
0      1      Marketing Intern      US, NY, New York
1      2  Customer Service - Cloud Video Production      NZ, , Auckland
2      3  Commissioning Machinery Assistant (CMA)      US, IA, Wever
3      4      Account Executive - Washington DC      US, DC, Washington
4      5      Bill Review Manager      US, FL, Fort Worth

  department salary_range telecommuting has_company_logo has_questions \
0  Marketing          NaN              0              1              0
1   Success          NaN              0              1              0
2      NaN          NaN              0              1              0
3   Sales          NaN              0              1              0
4      NaN          NaN              0              1              1

  employment_type required_experience required_education \
0      Other      Internship          NaN
1  Full-time      Not Applicable          NaN
2      NaN          NaN          NaN
3  Full-time  Mid-Senior level  Bachelor's Degree
4  Full-time  Mid-Senior level  Bachelor's Degree

          industry          function  fraudulent
0          NaN      Marketing              0
1  Marketing and Advertising  Customer Service              0
2          NaN          NaN              0
3      Computer Software      Sales              0
4  Hospital & Health Care  Health Care Provider              0

```

```

[ ]: df[
    ['job_id',
     'company_profile',
     'description',
     'requirements',
     'benefits'
    ]

```

```
] .head(1)
```

```
[ ]:  job_id  \
      0      1
```

```
company_profile  \
```

```
0  We're Food52, and we've created a groundbreaking and award-winning cooking
site. We support, connect, and celebrate home cooks, and give them everything
they need in one place. We have a top editorial, business, and engineering team.
We're focused on using technology to find new and better ways to connect people
around their specific food interests, and to offer them superb, highly curated
information about food and cooking. We attract the most talented home cooks and
contributors in the country; we also publish well-known professionals like Mario
Batali, Gwyneth Paltrow, and Danny Meyer. And we have partnerships with Whole
Foods Market and Random House. Food52 has been named the best food website by the
James Beard Foundation and IACP, and has been featured in the New York Times,
NPR, Pando Daily, TechCrunch, and on the Today Show. We're located in Chelsea, in
New York City.
```

```
description  \
```

```
0  Food52, a fast-growing, James Beard Award-winning online food community and
crowd-sourced and curated recipe hub, is currently interviewing full- and part-
time unpaid interns to work in a small team of editors, executives, and
developers in its New York City headquarters. Reproducing and/or repackaging
existing Food52 content for a number of partner sites, such as Huffington Post,
Yahoo, BuzzFeed, and more in their various content management systems. Researching
blogs and websites for the Provisions by Food52 Affiliate Program. Assisting in
day-to-day affiliate program support, such as screening affiliates and assisting
in any affiliate inquiries. Supporting with PR & Events when needed. Helping
with office administrative work, such as filing, mailing, and preparing for
meetings. Working with developers to document bugs and suggest improvements to the
site. Supporting the marketing and executive staff.
```

```
requirements  \
```

```
0  Experience with content management systems a major plus (any blogging
counts!) Familiar with the Food52 editorial voice and aesthetic. Loves food,
appreciates the importance of home cooking and cooking with the
seasons. Meticulous editor, perfectionist, obsessive attention to detail, maddened
by typos and broken links, delighted by finding and fixing them. Cheerful under
pressure. Excellent communication skills. A+ multi-tasker and juggler of
responsibilities big and small. Interested in and engaged with social media like
Twitter, Facebook, and Pinterest. Loves problem-solving and collaborating to drive
Food52 forward. Thinks big picture but pitches in on the nitty gritty of running a
small company (dishes, shopping, administrative support). Comfortable with the
realities of working for a startup: being on call on evenings and weekends, and
working long hours.
```

```
benefits
0      NaN
```

Results: Our dataset we loaded seems to match the structure we expect from Kaggle and now we will keep doing further discovery.

Purpose: Get a high-level summary of our data's structure.

```
[ ]: df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 17880 entries, 0 to 17879
Data columns (total 18 columns):
#   Column                Non-Null Count  Dtype
---  -
0   job_id                17880 non-null  int64
1   title                 17880 non-null  object
2   location              17534 non-null  object
3   department            6333 non-null   object
4   salary_range          2868 non-null   object
5   company_profile       14572 non-null   object
6   description            17879 non-null   object
7   requirements           15184 non-null   object
8   benefits              10668 non-null   object
9   telecommuting         17880 non-null   int64
10  has_company_logo       17880 non-null   int64
11  has_questions          17880 non-null   int64
12  employment_type        14409 non-null   object
13  required_experience     10830 non-null   object
14  required_education     9775 non-null    object
15  industry               12977 non-null   object
16  function               11425 non-null   object
17  fraudulent             17880 non-null   int64
dtypes: int64(5), object(13)
memory usage: 2.5+ MB
```

Results: From using the “info()” function we understand that we have the 18 columns that we expect, the 17,880 rows we expect, and we understand at a high-level our data types, and how many “non-null” values we have for each column. Next let’s dig deeper into the Null fields we have.

Purpose: From order of greatest to least, we want to see what percentage of a given fields values are Null, we also want to start thinking about which fields we can probably use for our Data Science Model. If a field has too many Nulls or if real-world job posting don’t have that data then we may suggest to drop those fields.

```
[ ]: def inspect_data(df: pd.DataFrame) -> pd.DataFrame:
      """
```

Inspect the dataset for missing values, datatypes, and number of unique values.

Args:

(Pandas DataFrame): DataFrame to inspect.

Returns:

Summary Pandas DataFrame with information per column.

"""

try:

```
summary = pd.DataFrame({
    'Data Type': df.dtypes,
    'Missing Values': df.isnull().sum(),
    'Missing %': round((df.isnull().mean() * 100), 2),
    'Unique Values': df.nunique(),
    # 'Sample Value': df.iloc[0]
})
summary = summary.sort_values(by='Missing %', ascending=False)
logging.info("Data inspection completed.")
return summary
except Exception as e:
    logging.error(f"Error during data inspection: {e}")
    raise
```

Run inspection

```
data_summary = inspect_data(df)
```

```
data_summary
```

INFO: Data inspection completed.

```
[ ]:
```

	Data Type	Missing Values	Missing %	Unique Values
salary_range	object	15012	83.96	874
department	object	11547	64.58	1337
required_education	object	8105	45.33	13
benefits	object	7212	40.34	6203
required_experience	object	7050	39.43	7
function	object	6455	36.10	37
industry	object	4903	27.42	131
employment_type	object	3471	19.41	5
company_profile	object	3308	18.50	1709
requirements	object	2696	15.08	11965
location	object	346	1.94	3105
description	object	1	0.01	14801
title	object	0	0.00	11231
job_id	int64	0	0.00	17880
telecommuting	int64	0	0.00	2

has_questions	int64	0	0.00	2
has_company_logo	int64	0	0.00	2
fraudulent	int64	0	0.00	2

Results: Suggested that we Drop the following Columns later on: salary_range, department, required_education, benefits, required_experience, function, industry, location, job_id, has_questions, has_company_logo.

We recommend dropping the above fields because some of them aren't useful in identifying fraudulent jobs even if the columns didn't have so many nulls. For other columns, when looking at real world job posting, we don't always see this information and ideally we want the fields used in our training data to match the real-world as closely as possible.

Purpose: Checking for Duplicate Rows of Data to see if we need to de-duplicate our dataset later on.

```
[ ]: def check_duplicates(df, subset=None):
    """
    Check a DataFrame for duplicate rows and return statistics.

    Parameters:
    -----
    df : pandas.DataFrame
        The DataFrame to check for duplicates
    subset : list, optional
        List of column names to consider for identifying duplicates.
        If None, use all columns.

    Returns:
    -----
    dict
        Dictionary containing:
        - 'has_duplicates': Boolean indicating if duplicates exist
        - 'duplicate_count': Number of duplicate rows
        - 'duplicate_rows': DataFrame containing only the duplicate rows
        - 'value_counts': Series showing counts for each duplicated row
    """
    # Get value counts for each unique row combination
    if subset is None:
        value_counts = df.value_counts()
    else:
        value_counts = df.value_counts(subset=subset)

    # Find rows with count > 1 (duplicates)
    duplicated_rows = value_counts[value_counts > 1]

    # Calculate total number of duplicate rows (excluding first occurrences)
```

```

duplicate_count = sum(count - 1 for count in duplicated_rows)

# Find the actual duplicate rows in the DataFrame
if subset is None:
    mask = df.duplicated(keep=False)
else:
    mask = df.duplicated(subset=subset, keep=False)

duplicate_rows_df = df[mask].copy()

# Return results as a dictionary
result = {
    'has_duplicates': len(duplicated_rows) > 0,
    'duplicate_count': duplicate_count,
    'duplicate_rows': duplicate_rows_df,
    'value_counts': duplicated_rows
}

return result

# Check for dupes:
num_duplicates = check_duplicates(df)
print(f"Has duplicates: {num_duplicates['has_duplicates']}")
print(f"Number of duplicate rows: {num_duplicates['duplicate_count']}")
print("Duplicate rows:")
print(num_duplicates['duplicate_rows'])

```

```

Has duplicates: False
Number of duplicate rows: 0
Duplicate rows:
Empty DataFrame
Columns: [job_id, title, location, department, salary_range, company_profile,
description, requirements, benefits, telecommuting, has_company_logo,
has_questions, employment_type, required_experience, required_education,
industry, function, fraudulent]
Index: []

```

Results: Seems like we don't have any duplicate rows of data in our dataset so we won't need to do any "de-duplication" in our "Cleaning" step.

Purpose: The purpose of the below function is to visualize the distribution of values in categorical and binary columns from the dataset. For each specified column, it generates a horizontal bar chart that shows how frequently each category or value appears. This helps in understanding the balance, skewness, and patterns within categorical variables, which is critical for exploratory data analysis and for identifying potential data issues (such as class imbalance).

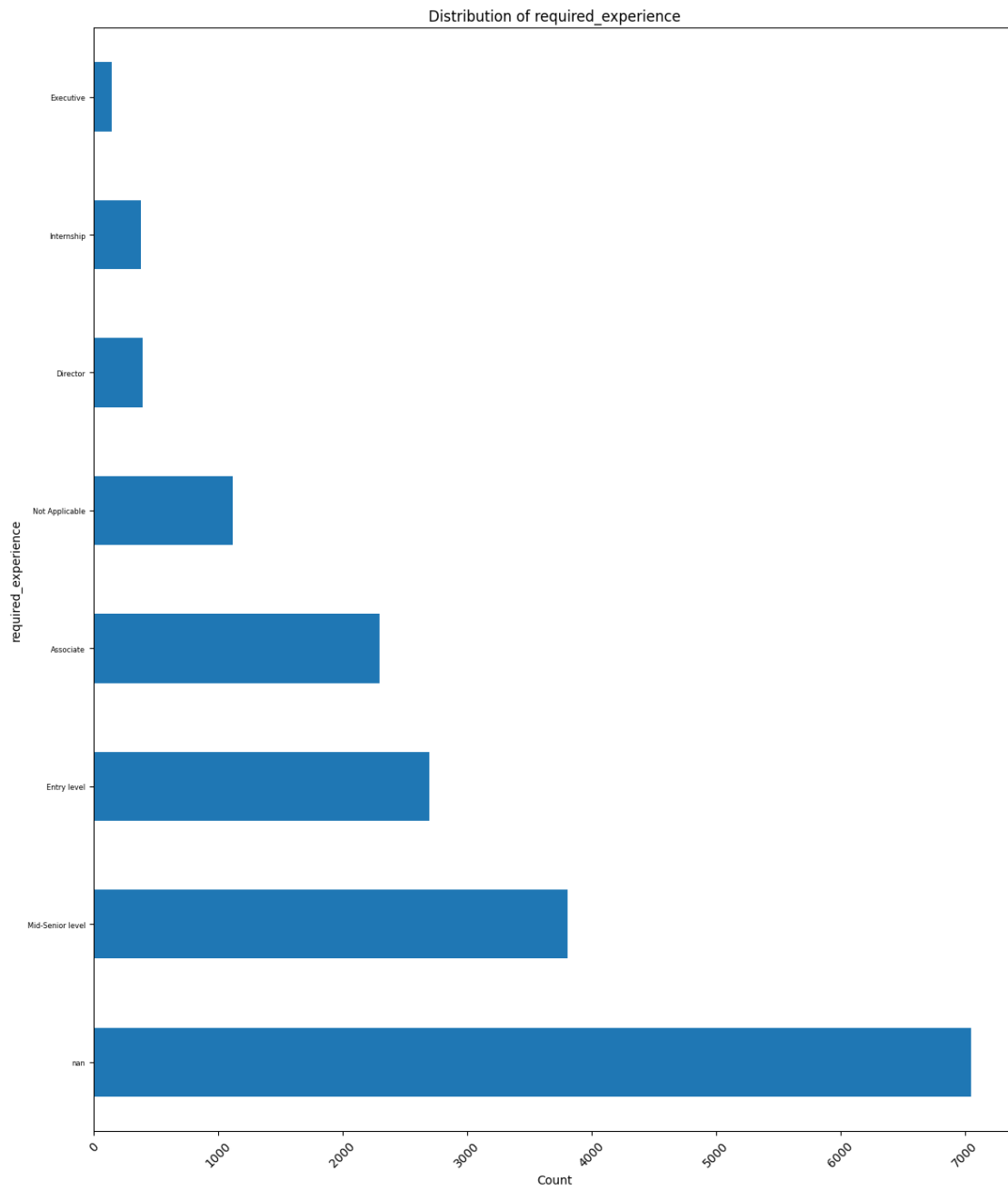

```
[ ]: def plot_categorical_distributions(df: pd.DataFrame, columns: list):
    """
    Plot bar charts for categorical columns to show value distributions.

    Args:
        df (pd.DataFrame): The dataset.
        columns (list): List of categorical & binary column names.
    """
    for col in columns:
        try:
            plt.figure(figsize=(12, 14))
            df[col].value_counts(dropna=False).plot(kind='barh')
            plt.title(f'Distribution of {col}')
            plt.xlabel('Count')
            plt.ylabel(col)
            plt.xticks(rotation=45)
            plt.yticks(fontsize=6)
            plt.tight_layout()
            plt.show()
        except Exception as e:
            logging.error(f"Failed to plot distribution for {col}: {e}")

    # Select categorical and binary columns to visualize
    categorical_columns = [
        'employment_type', 'required_experience', 'required_education',
        'industry', 'function', 'telecommuting', 'has_company_logo',
        'has_questions', 'fraudulent'
    ]

    # Plot value distributions
    plot_categorical_distributions(df, categorical_columns)
```



















Results: After visualizing our data, we understand that our dataset has class imbalance because we have many more real jobs than fraudulent jobs. We will have to keep this in mind as we build our data science model.

Target Variable: fraudulent

Imbalanced classes:

0 (Real jobs) dominate the dataset.

1 (Fake jobs) are a minority.

We'll need to address this imbalance during modeling (e.g., SMOTE, stratified sampling).

Purpose: This function is designed to visualize the correlation relationships between selected numerical columns in the dataset. It computes the pairwise correlation matrix and plots it as a heatmap, where the strength and direction of the relationships are represented by color intensity. This helps in identifying strong positive or negative correlations between variables, which can inform feature selection, detect multicollinearity, or guide further analysis.

Correlation is a measure that shows the relationship between two variables. It ranges from -1 to +1:

Positive (+1) -> Strong positive correlation - as one goes up, the other also goes up.

Negative (-1) -> Strong negative correlation - as one goes up, the other goes down.

None (0) -> No correlation - they don't move together in any predictable way.

```
[ ]: import seaborn as sns

def plot_correlation_heatmap(df: pd.DataFrame, numeric_cols: list):
    """
    Plot a heatmap showing correlation between numerical columns.

    Args:
        Pandas Dataframe (pd.DataFrame): The dataset.
        numeric_cols (list): List of numerical column names.
    """
    try:
        corr_matrix = df[numeric_cols].corr()
        plt.figure(figsize=(8, 6))
        sns.heatmap(corr_matrix, annot=True, fmt=".2f", cmap='coolwarm',
                    cbar=True)
        plt.title('Correlation Heatmap of Numeric Variables')
        plt.tight_layout()
        plt.show()
    except Exception as e:
        logging.error(f"Error plotting correlation heatmap: {e}")
        raise

# Define numeric columns
numeric_columns = ['telecommuting', 'has_company_logo', 'has_questions',
                  'fraudulent']

# Plot correlation heatmap
plot_correlation_heatmap(df, numeric_columns)
```



Results:

1. Field: has_company_logo

- Correlation with fraudulent: negative
- Meaning: If a job has a company logo ($\text{has_company_logo} = 1$), it's less likely to be fake
- So: Fake jobs often don't have logos \rightarrow makes sense.

2. Field: has_questions

- Correlation with fraudulent: positive
- Meaning: If $\text{has_questions} = 1$ (i.e., the job does have screening questions), it's more likely to be fake
- But this seems counterintuitive? You'd think real jobs use questions more?

3. Explanation?

The opposite is more likely true in most real-world cases:

Real jobs do include screening questions. Fake jobs tend to skip them, because they want to look easy/appealing.

So, if `has_questions` has a positive correlation with `fraudulent`, it might be due to:

3.1 - Noise or imbalance in the data.

3.2 - Possible feature encoding error.

3.3 - Or the correlation is very weak and not meaningful in practice.

Conclusion:

A positive correlation with `fraudulent` means that as the other variable increases (e.g., `has_questions = 1`), the likelihood of being fake (`fraudulent = 1`) also increases.

But correlation only shows association, not causation.

1.2.2 Step 2: Structuring

Structuring data transforms features to uniform formats, units, and scales.

Purpose: Format text fields in a uniform format

```
[ ]: import re

def format_text(text: str) -> str:
    """
    Clean the input text converting to lowercase and removing whitespaces. We
    ↪will leave non-ascii characters as it could be an indicator of a fraudulent
    ↪job.
    Args:
        text (str): The input text to be cleaned.

    Returns:
        str: The cleaned text
    """
    if not isinstance(text, str):
        raise ValueError("Input must be a string.")
    text = text.lower()
    text = re.sub(r'[\W\s]', '', text)
    return text

df['description'] = df['description'].apply(format_text)
df['requirements'] = df['requirements'].apply(format_text)
df['title'] = df['title'].apply(format_text)
df['company_profile'] = df['company_profile'].apply(format_text)
```

Results: Now the text fields we care about for our model are formatted consistently, which will be especially useful when applying TF-IDF. Due to the nature of our dataset we did not have to

do too much structuring to it.

1.2.3 Step 3: Cleaning

Cleaning data removes or replaces missing and outlier data.

Purpose: We saw earlier in a table that we have certain columns with missing data ordered by percentage, now we either want to drop/filter those columns out of our dataset also because they have poor real-world usability for our Data Science Model.

```
[ ]: # Count and display percentage of missing values:
missing_percent = (df.isnull().sum() / len(df)) * 100
missing_percent = missing_percent[missing_percent > 0].
    ↪sort_values(ascending=False)

plt.figure(figsize=(10, 6))
missing_percent.plot(kind='bar', color='orange')
plt.title('Percentage of Missing Values by Column')
plt.ylabel('% of Missing Values')
plt.xlabel('Columns')
plt.show()
```



Results: We've visualized some of the fields we intend to filter in the coming steps.

Purpose: We want to filter the dataframe to only have our feature and target columns since some of the other fields have too many nulls or are not usable for our goals and have poor real-world application.

Features:

- Text: title, description, requirements, company_profile
- Structured: employment_type (Categorical), telecommuting (Boolean)

Target: - fraudulent

```
[ ]: def filter_dataframe(df: pd.DataFrame, required_columns: List[str]) -> pd.
    DataFrame:
        """
        Filters the input DataFrame to retain only the specified columns, in the
        given order.

        Parameters
        -----
        df: pd.DataFrame - The input DataFrame to process.

        required_columns: List[str]
            A list of columns that must be present in the DataFrame. Only these
            columns will be retained, in this order.

        Returns
        -----
        pd.DataFrame: A new DataFrame containing only the specified columns, in the
        specified order.

        Raises
        -----
        ValueError: If any of the required columns are missing in the input
        DataFrame.
        """
        missing = set(required_columns) - set(df.columns)
        if missing:
            raise ValueError(f"Missing required column(s): {' '.join(missing)}")

        return df[required_columns]

required_columns = [
    "job_id",
```

```

        "title",
        "description",
        "requirements",
        "company_profile",
        "employment_type",
        "telecommuting",
        "fraudulent"
    ]

    filtered_df = filter_dataframe(df, required_columns)

```

```
[ ]: filtered_df.info()
```

```

<class 'pandas.core.frame.DataFrame'>
RangeIndex: 17880 entries, 0 to 17879
Data columns (total 8 columns):
#   Column                Non-Null Count  Dtype
---  -
0   job_id                17880 non-null  int64
1   title                 17880 non-null  object
2   description           17879 non-null  object
3   requirements          15184 non-null  object
4   company_profile       14572 non-null  object
5   employment_type       14409 non-null  object
6   telecommuting         17880 non-null  int64
7   fraudulent            17880 non-null  int64
dtypes: int64(3), object(5)
memory usage: 1.1+ MB

```

Results: Now we have only our feature and target columns along with the “job_id” field to easily identify a given row.

Purpose: This function is responsible for cleaning the dataset by addressing missing or incomplete data in key text and categorical fields. Specifically, it performs two main operations:

1. Row Removal: It drops rows where all of the major text fields (title, description, requirements, company_profile) are missing, as such records provide no useful information.
2. Value Imputation: It fills missing or blank values in the employment_type column with the placeholder value ‘Unknown’, ensuring consistent treatment of missing employment data.

This cleaning step improves data quality by removing irrelevant records and standardizing missing values, making the dataset more reliable for analysis and modeling.

```

[ ]: def clean_dataset(df: pd.DataFrame) -> pd.DataFrame:
      """
      Cleans the dataset by applying the following transformations:
      1. Drops rows where all four specified text columns are missing (NaN).

```


2. Fills missing and empty string values in the 'employment_type' column with 'Unknown'.

Parameters

df: pd.DataFrame - The input DataFrame to clean.

Returns

pd.DataFrame - A cleaned DataFrame with the specified transformations applied.

"""

```
text_columns = ['title', 'description', 'requirements', 'company_profile']
rows_before = len(df)
```

```
# Drop rows where all text columns are missing:
```

```
df_cleaned = df.dropna(subset=text_columns, how='all')
```

```
rows_after = len(df_cleaned)
```

```
dropped = rows_before - rows_after
```

```
# Fill missing or blank 'employment_type' with 'Unknown':
```

```
df_cleaned['employment_type'] = df_cleaned['employment_type'].apply(lambda x: 'Unknown' if pd.isna(x) or str(x).strip() == '' else x)
```

```
print(f"[INFO] Dropped {dropped} rows with all text fields missing.")
```

```
print(f"[INFO] Filled 'employment_type' blanks and NaNs with 'Unknown'.")
```

```
return df_cleaned
```

```
# Supply the filtered dataframe from the previous step:
```

```
cleaned_df = clean_dataset(filtered_df)
```

```
[INFO] Dropped 0 rows with all text fields missing.
```

```
[INFO] Filled 'employment_type' blanks and NaNs with 'Unknown'.
```

Results: We now have our cleaned dataframe and can continue with the next steps.

1.2.4 Step 4: Enriching

Enriching data derives new features from existing features and appends new data from external sources.

Purpose We will add metadata around the description feature as it is our main text feature. Specifically, we are looking to add word count, readability using the flesch reading ease score, and complexity score using the text standard in textstat as these can all be an indicator of fraud.

```
[ ]: import textstat

cleaned_df[f'description_wordcount'] = cleaned_df['description'].astype(str).
    ↪ apply(lambda x: len(x.split()))
cleaned_df[f'description_readability'] = cleaned_df['description'].astype(str).
    ↪ apply(textstat.flesch_reading_ease).fillna(0).astype(float)
cleaned_df[f'description_complexity_score'] = cleaned_df['description'].
    ↪ astype(str).apply(lambda x: textstat.text_standard(x, float_output=True)).
    ↪ fillna(0).astype(float)
cleaned_df[f'company_profile_wordcount'] = cleaned_df['company_profile'].
    ↪ astype(str).apply(lambda x: len(x.split()))
cleaned_df[f'company_profile_readability'] = cleaned_df['company_profile'].
    ↪ astype(str).apply(textstat.flesch_reading_ease).fillna(0).astype(float)
cleaned_df[f'company_profile_complexity_score'] = cleaned_df['company_profile'].
    ↪ astype(str).apply(lambda x: textstat.text_standard(x, float_output=True)).
    ↪ fillna(0).astype(float)

cleaned_df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
```

```
RangeIndex: 17880 entries, 0 to 17879
```

```
Data columns (total 14 columns):
```

#	Column	Non-Null Count	Dtype
0	job_id	17880 non-null	int64
1	title	17880 non-null	object
2	description	17879 non-null	object
3	requirements	15184 non-null	object
4	company_profile	14572 non-null	object
5	employment_type	17880 non-null	object
6	telecommuting	17880 non-null	int64
7	fraudulent	17880 non-null	int64
8	description_wordcount	17880 non-null	int64
9	description_readability	17880 non-null	float64
10	description_complexity_score	17880 non-null	float64
11	company_profile_wordcount	17880 non-null	int64
12	company_profile_readability	17880 non-null	float64
13	company_profile_complexity_score	17880 non-null	float64

```
dtypes: float64(4), int64(5), object(5)
```

```
memory usage: 1.9+ MB
```

Result We now have 13 features in our dataset, including key metadata about description and company_profile features.

1.2.5 Step 5: Validating

Validating data verifies that the dataset is internally consistent and accurate.

Purpose First, we will verify that our boolean-type features have only 0 and 1 for values.

```
[ ]: cleaned_df[['fraudulent', 'telecommuting']].value_counts()
```

```
[ ]: fraudulent  telecommuting
0              0              16311
1              0              802
0              1              703
1              1              64
Name: count, dtype: int64
```

Results We can see that only valid values of 0 and 1 exist in fraudulent and telecommuting features.

1.2.6 Step 6: Publishing

Now that we have completed our initial data wrangling, we can save our cleaned dataset in a git repository, upload it to Kaggle, or submit our final findings to the original dataset. This will allow others to benefit and learn from the modification we have done to the original dataset.

GitHub Repo for Project Fake Finder: <https://github.com/jdeleon3/Projects.RealFakeJobPredictor>

```
[ ]: # import os
# if os.path.exists('./data'):
#     cleaned_df.to_csv('./data/cleaned_job_postings.csv', index=False)
#     print("Cleaned dataset saved as 'cleaned_job_postings.csv'.")
```

Cleaned dataset saved as 'cleaned_job_postings.csv'.

1.3 Data Exploration

1.3.1 Step 1: Understand the data

Find the size of the dataset (number of rows and columns), identify and categorize the features (categorical, numerical).

1.3.2 Purpose

Now that we have a cleaned dataset, we should again evaluate what our dataset looks like, starting with its shape and the type of features included.

```
[ ]: print(f"{cleaned_df.shape[0]} rows and {cleaned_df.shape[1]} columns after_
      ↪cleaning.")

numeric_columns = cleaned_df.select_dtypes(include=[np.number]).columns.tolist()
text_columns = cleaned_df.select_dtypes(include=[object]).columns.tolist()

print(f"{len(numeric_columns)} Numeric columns: {numeric_columns}")
print(f"{len(text_columns)} Text columns: {text_columns}")
```

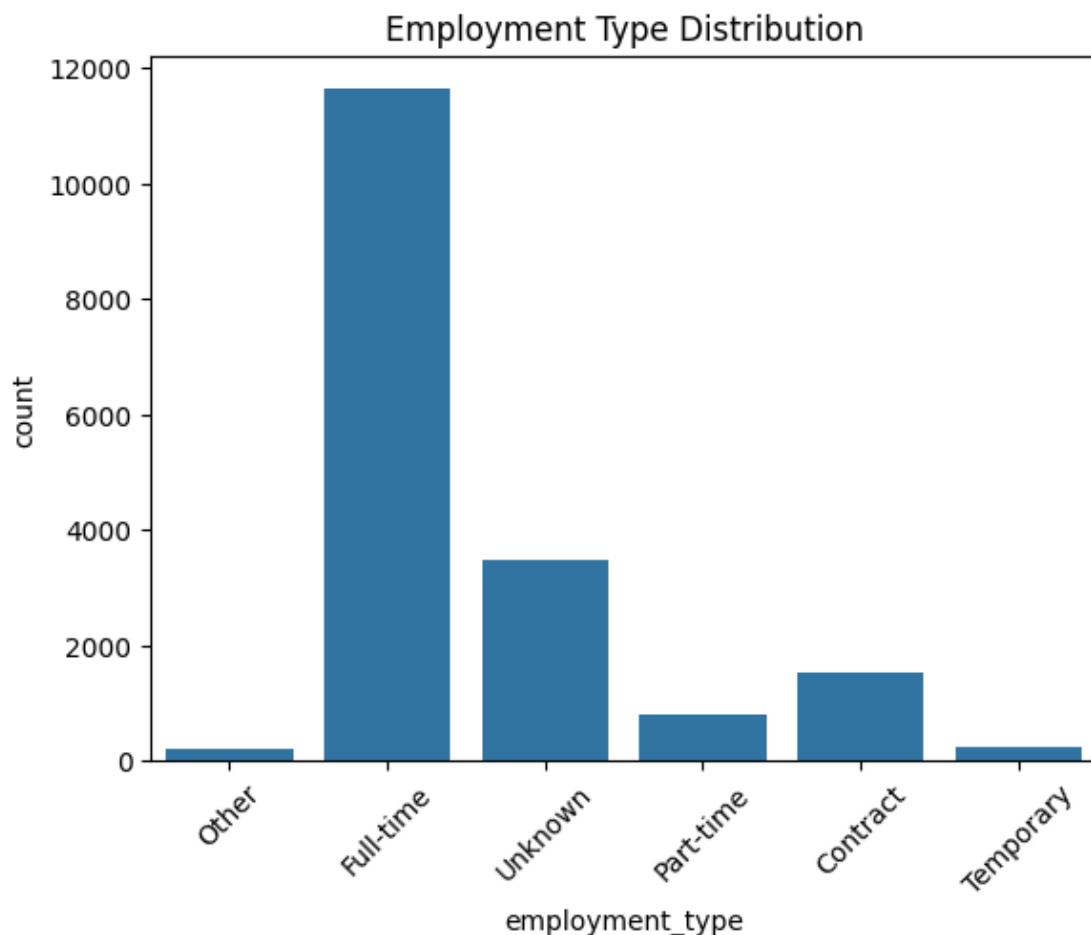
17880 rows and 14 columns after cleaning.

9 Numeric columns: ['job_id', 'telecommuting', 'fraudulent', 'description_wordcount', 'description_readability', 'description_complexity_score', 'company_profile_wordcount', 'company_profile_readability', 'company_profile_complexity_score']
5 Text columns: ['title', 'description', 'requirements', 'company_profile', 'employment_type']

Results After cleaning our dataset, we have 17880 row and 13 features (8 numeric and 5 text).

Purpose Part of understanding our data is looking for features that have an imbalance in values. The employment_type feature could be one of those features, as most job postings tend to be Full-time.

```
[ ]: sns.countplot(cleaned_df, x='employment_type')  
plt.title('Employment Type Distribution')  
plt.xticks(rotation=45)  
plt.show()
```



Results As expected, Full-time does have considerably more than all other types. We might consider combining some types if we find `employment_type` being overfit by the model, but for now, we will leave it as is.

1.3.3 Step 2: Identify relationships between features

Find the direction (positive, negative) and strength (strong, moderate, weak) of correlation between the features.

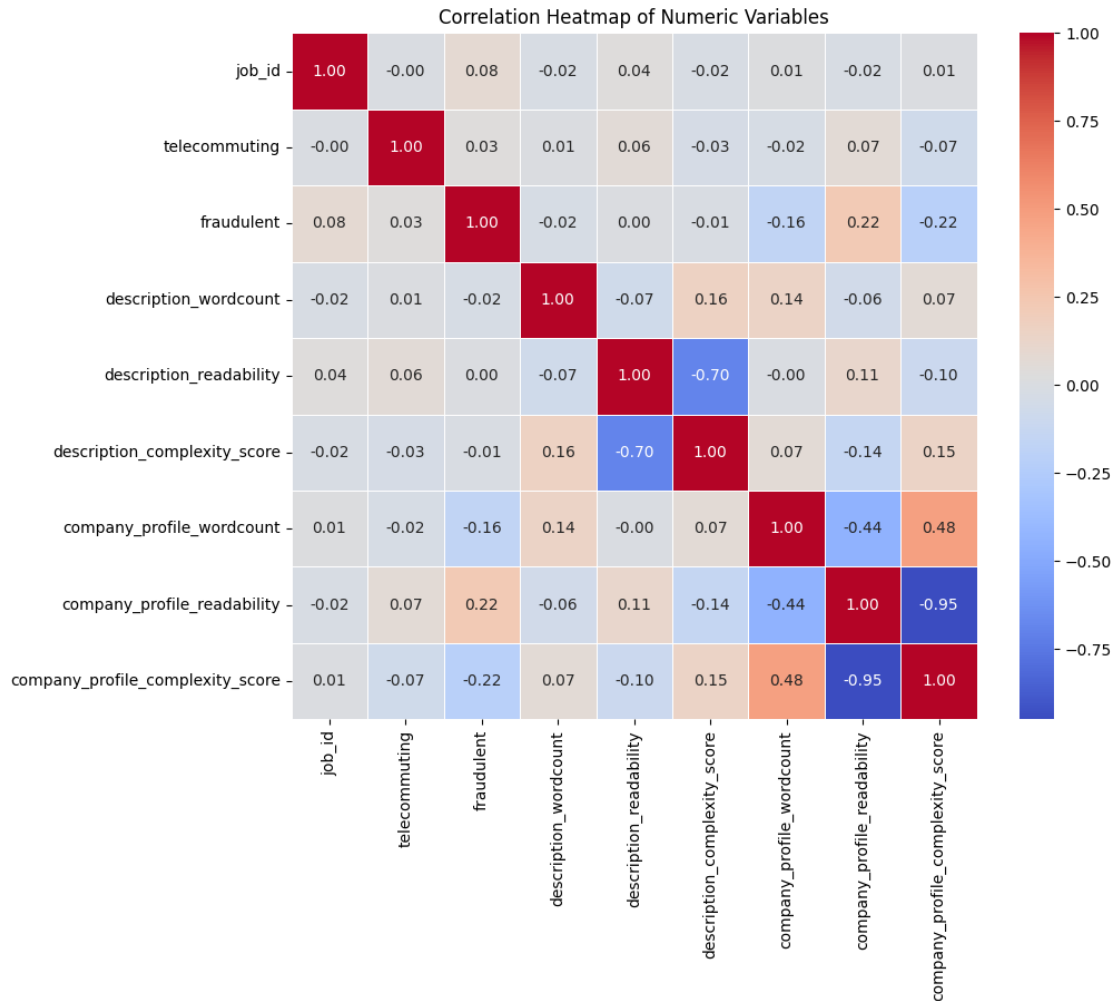
Purpose Next, we will verify that we do not have any highly coorelated features that can be combined. We will consider correlation values over 0.7 as candidates. To do this, we will look at a heatmap of the dataset features.

```
[ ]: corr_matrix = cleaned_df.select_dtypes(include=[np.number]).corr()
plt.figure(figsize=(10, 8))

sns.heatmap(corr_matrix, annot=True, fmt=".2f", cmap='coolwarm', cbar=True,
            square=True, linewidths=0.5)

plt.title('Correlation Heatmap of Numeric Variables')
plt.show()

cleaned_df.drop(columns=['descriptioin_complexity_score',
                        'company_profile_complexity_score'], inplace=True, errors='ignore')
```



Results We found that the readability features created during our Enriching step is negatively correlated with the complexity score feature. Since the correlation is above 0.70, we dropped company_profile_complexity_score and description_complexity_score features.

1.3.4 Step 3: Describe the Data

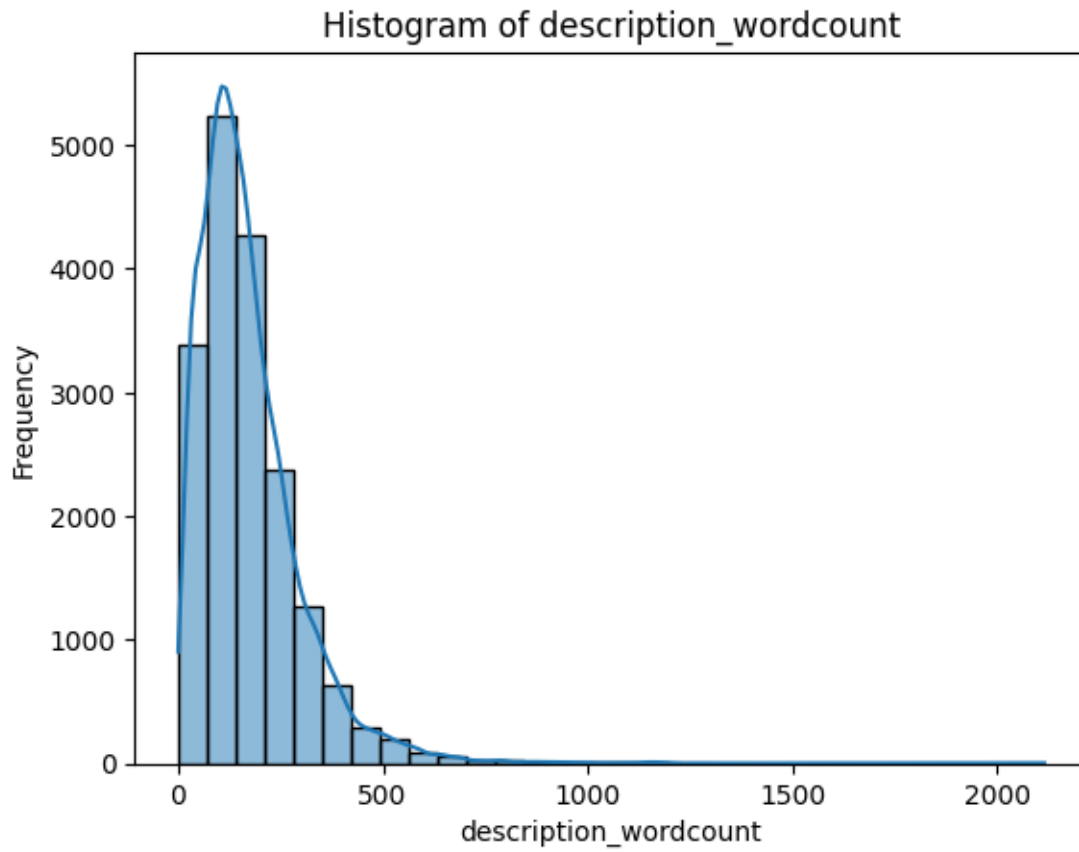
Determine the shape of the distribution (symmetric, skewed)

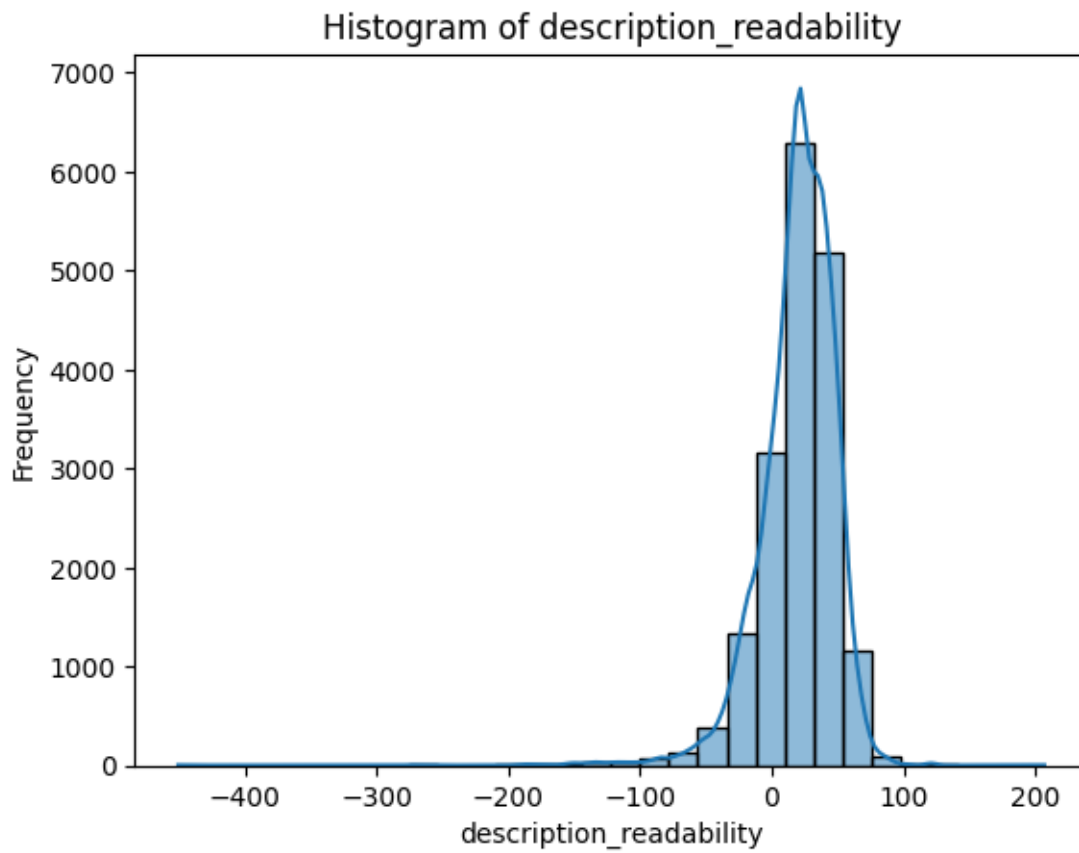
Purpose We will review the histogram plots of our engineered features to check their distribution.

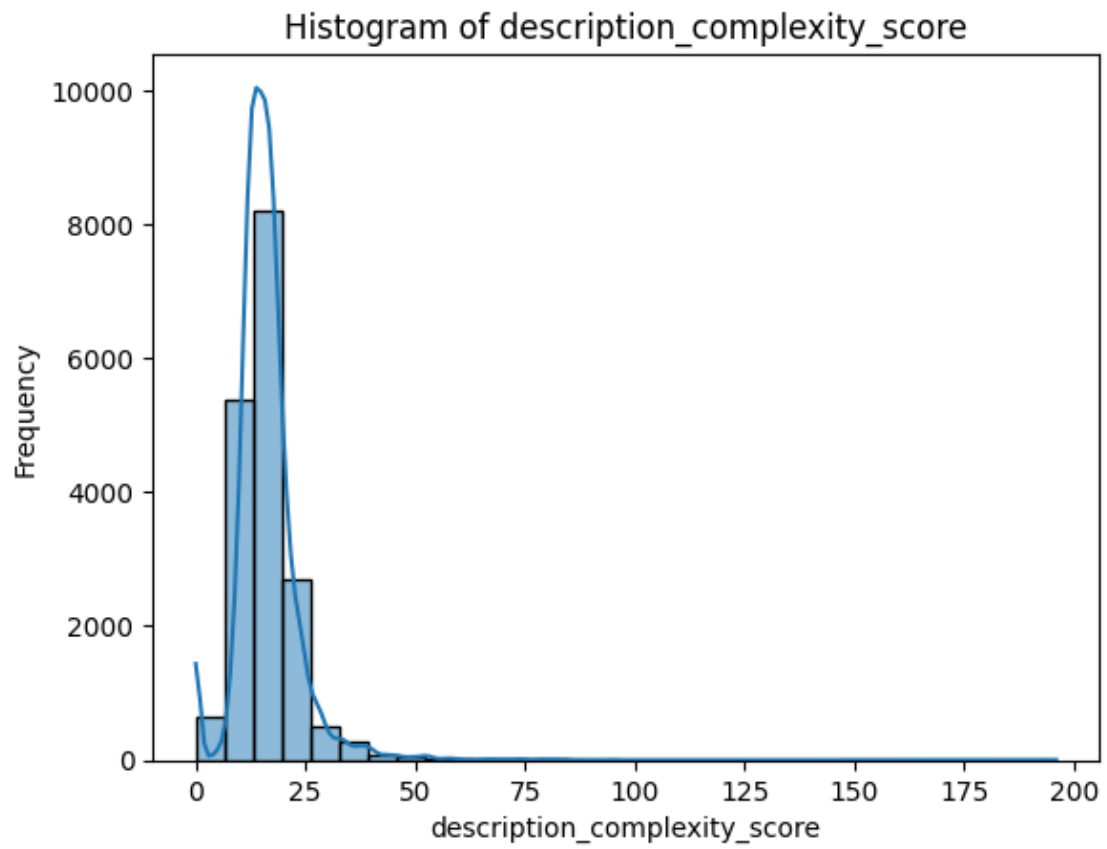
```
[ ]: numeric_columns = ['description_wordcount', 'description_readability',
    ↪ 'description_complexity_score', 'company_profile_wordcount',
    ↪ 'company_profile_readability']

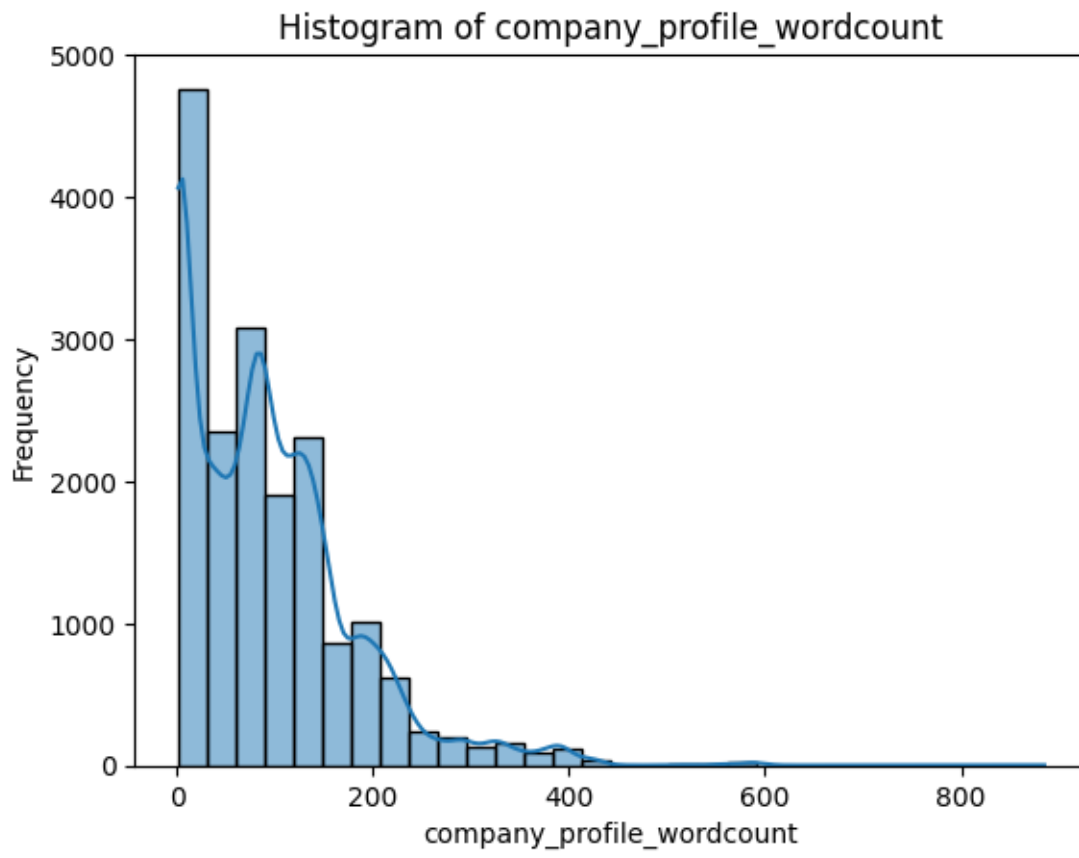
for col in numeric_columns:
    sns.histplot(cleaned_df[col], bins=30, kde=True)
```

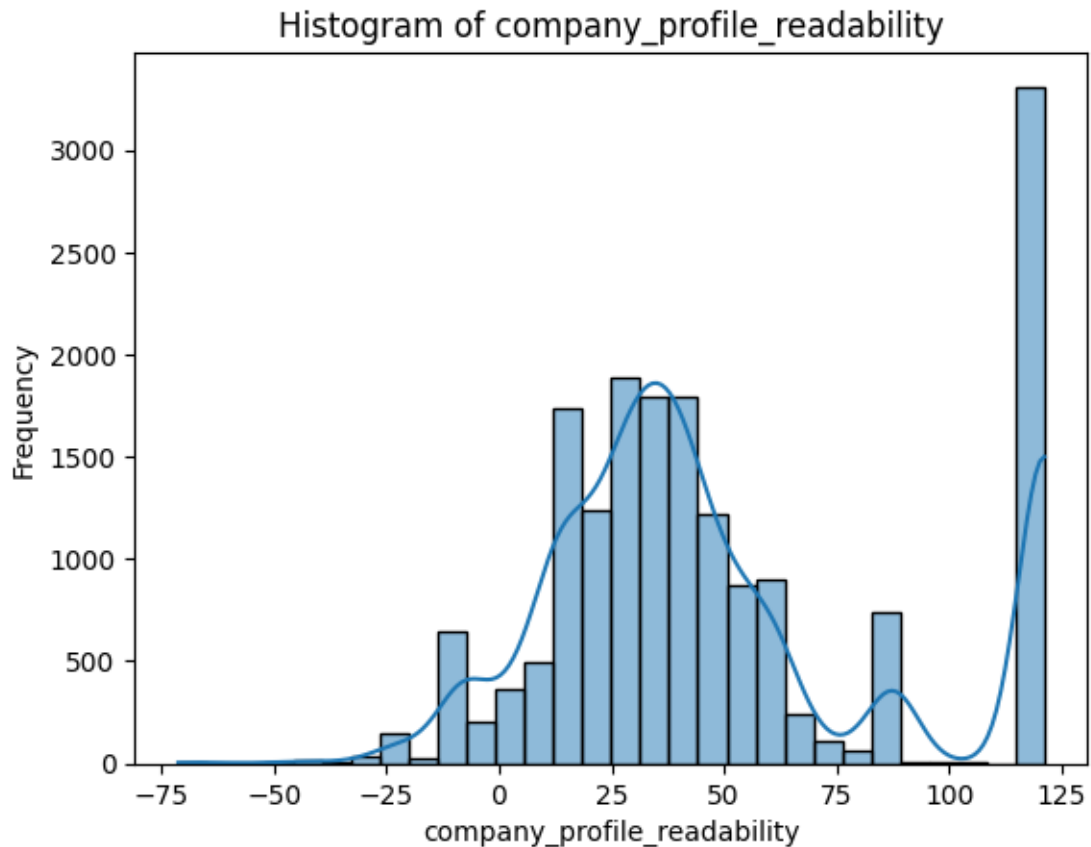
```
plt.title(f'Histogram of {col}')  
plt.xlabel(col)  
plt.ylabel('Frequency')  
plt.show()
```











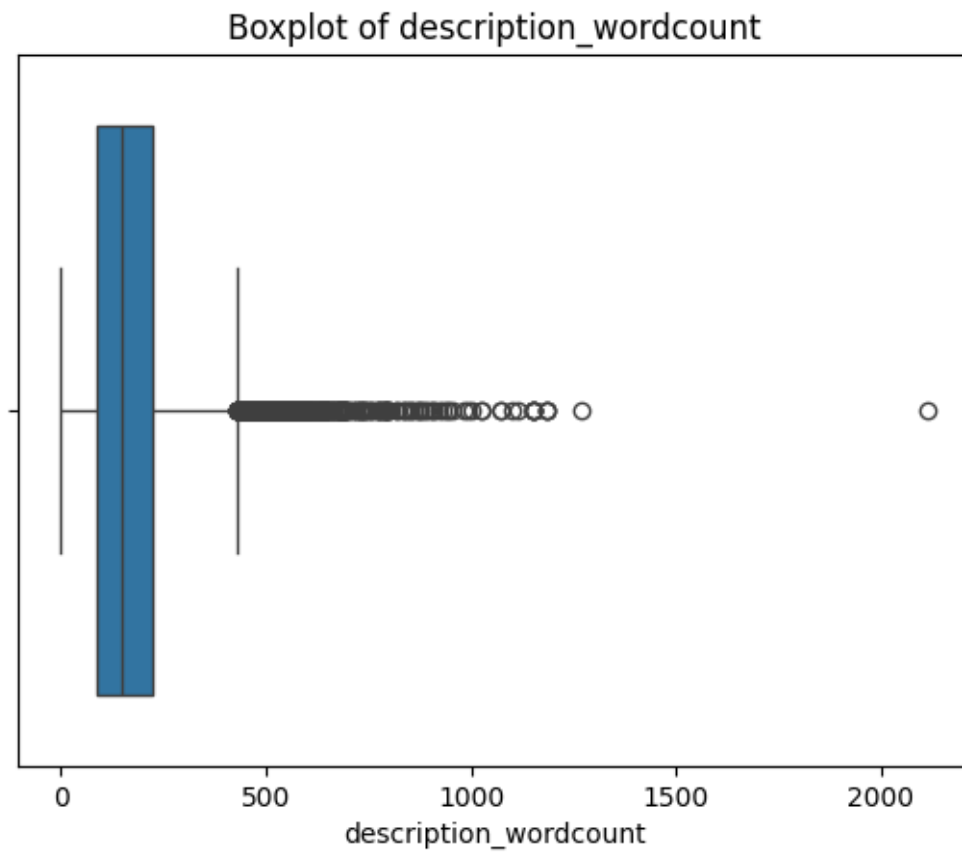
Results Each of the features are skewed. `Description_wordcount`, `company_profile_wordcount`, and `description_complexity_score` are all skewed right with a long tail while `company_profile_readability` and `description_readability` are skewed left with a long tail. This warrants further analysis to consider outliers.

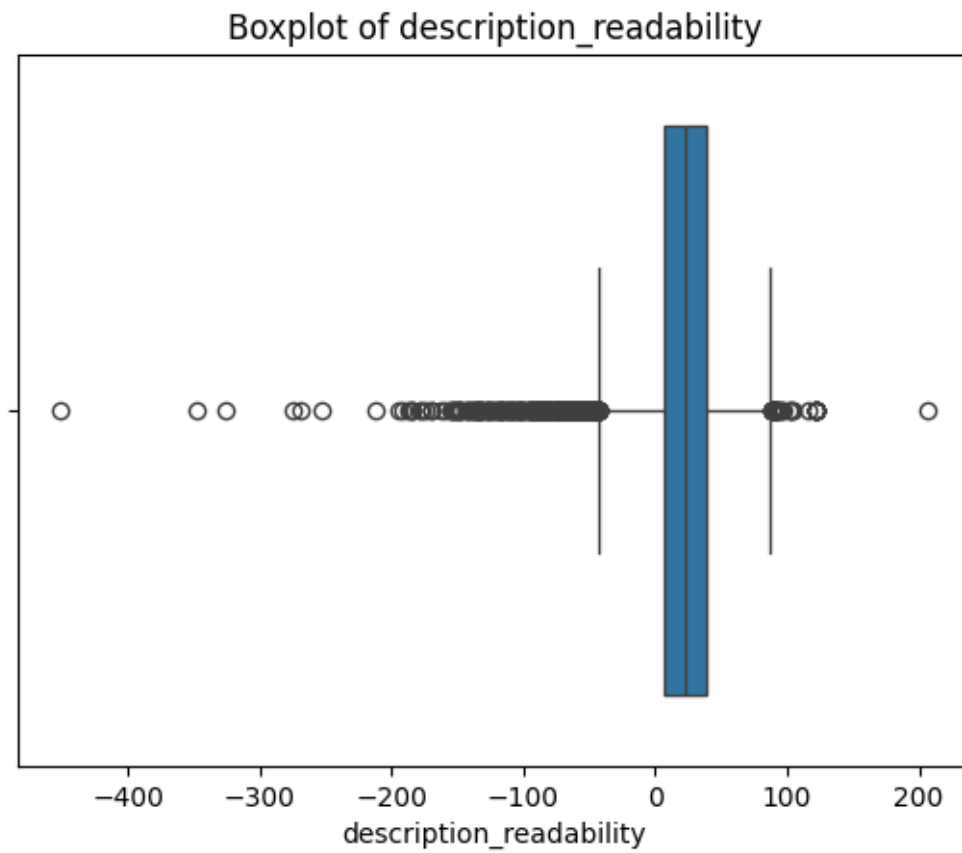
1.3.5 Step 4: Detect outliers and missing data

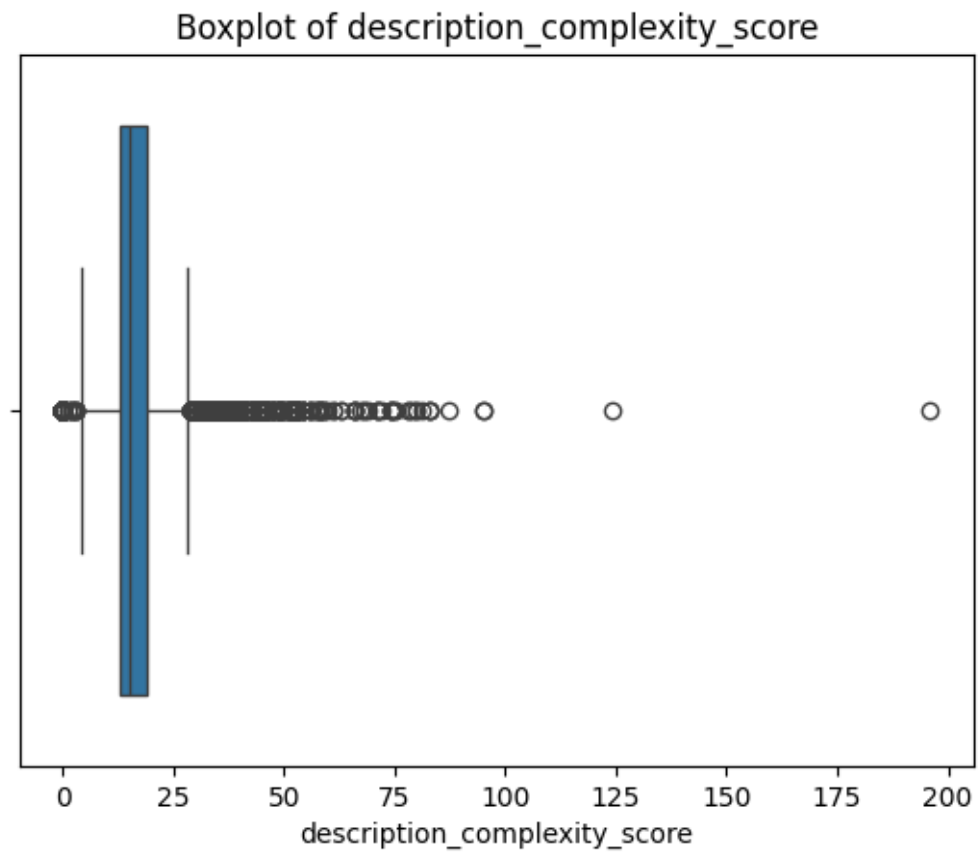
Find values that are much higher or lower than the rest of the data or values that strongly affect the shape of the data.

Purpose With our engineered features being skewed, we will look at the boxplot of each to identify if there are any outliers that should be addressed.

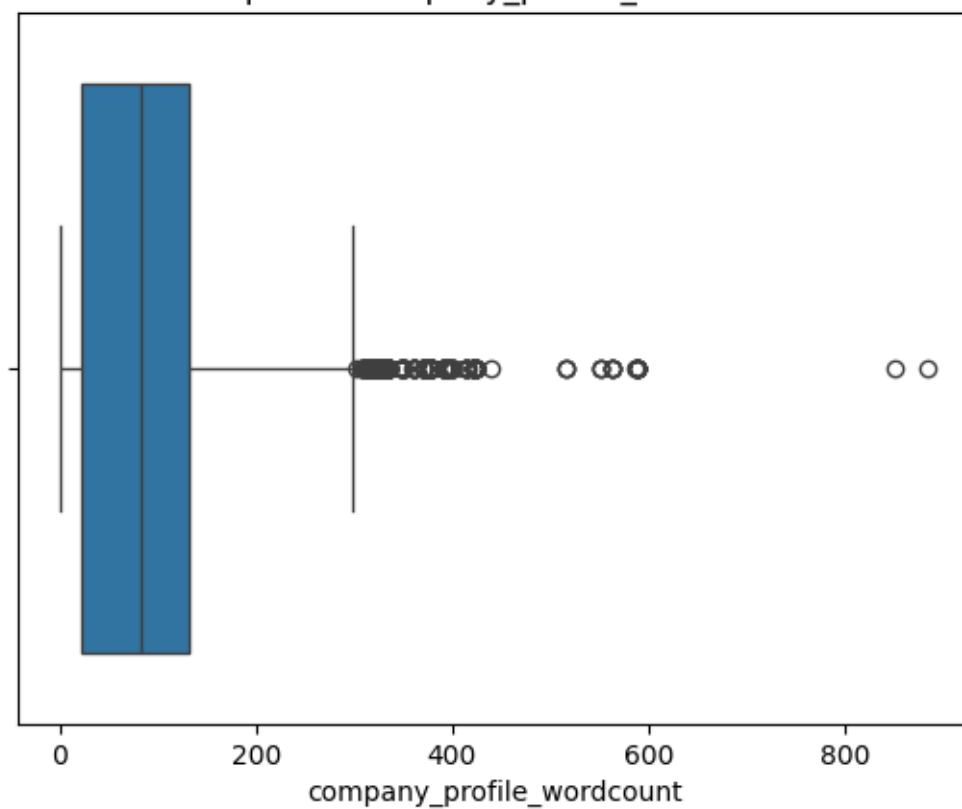
```
[ ]: for col in numeric_columns:
    sns.boxplot(data=cleaned_df, x=col)
    plt.title(f'Boxplot of {col}')
    plt.xlabel(col)
    plt.show()
```

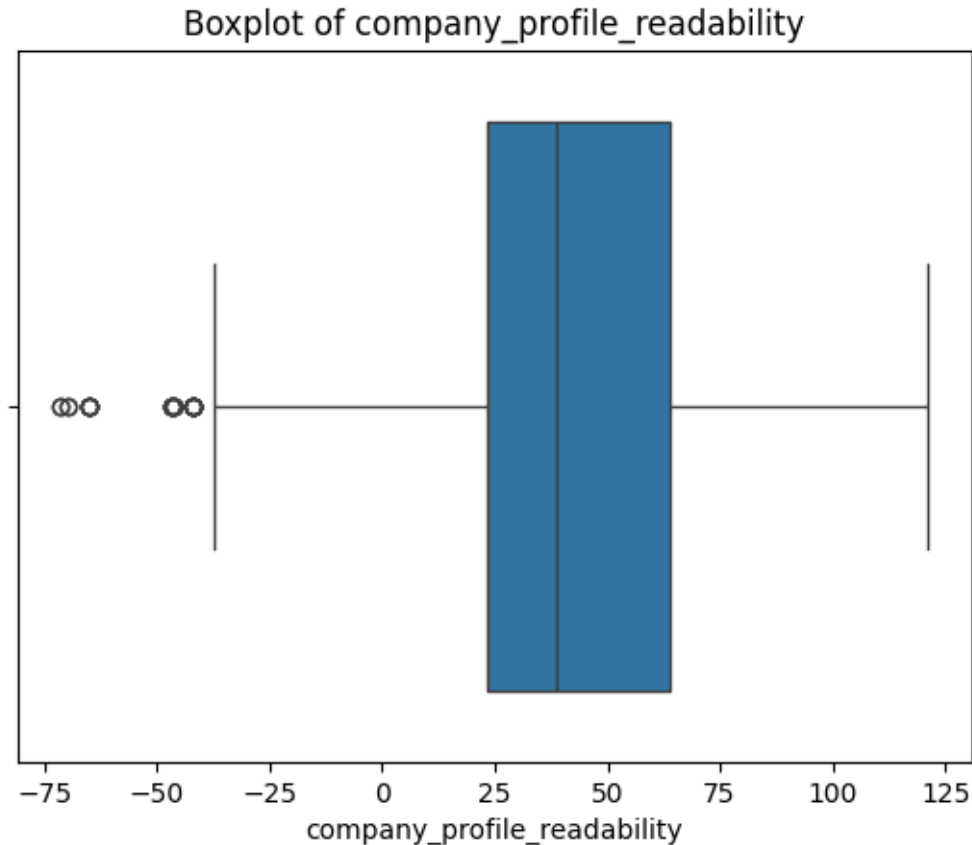






Boxplot of company_profile_wordcount





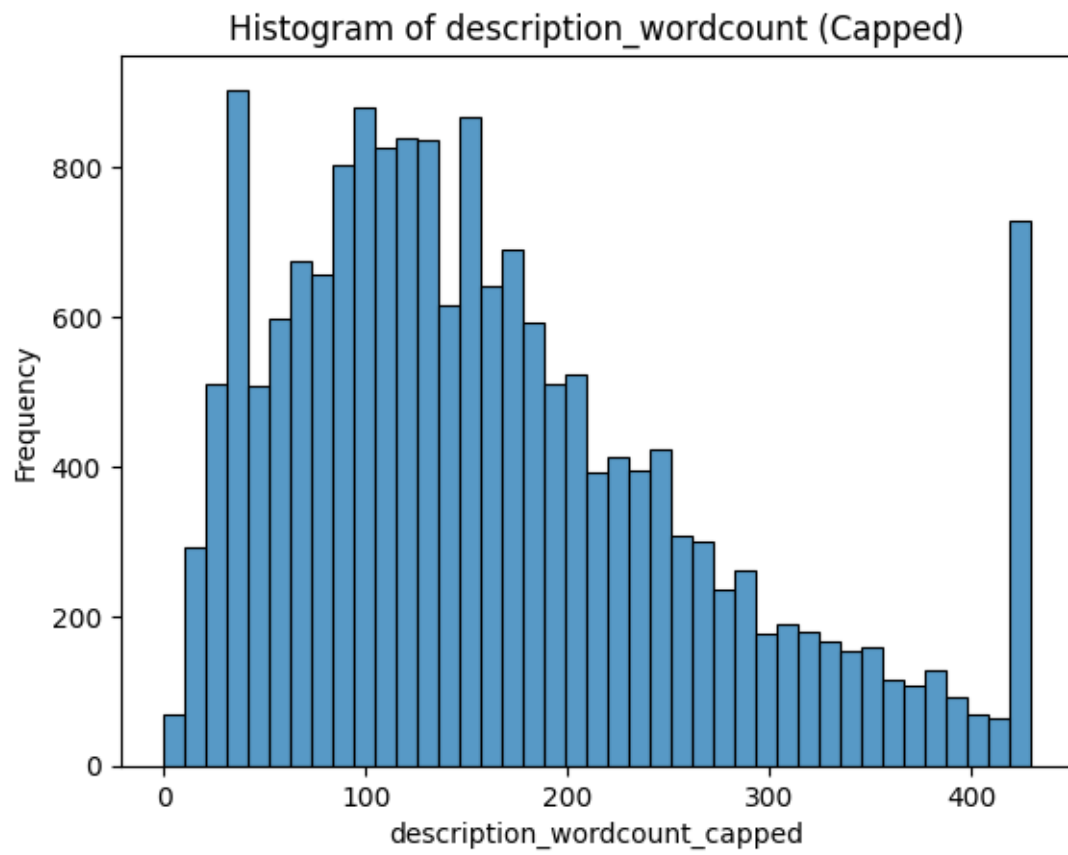
Results We can see that each of our engineered features have quite a few potential outliers. As outliers could be a signal for fraud, we do not want to completely remove our outliers.

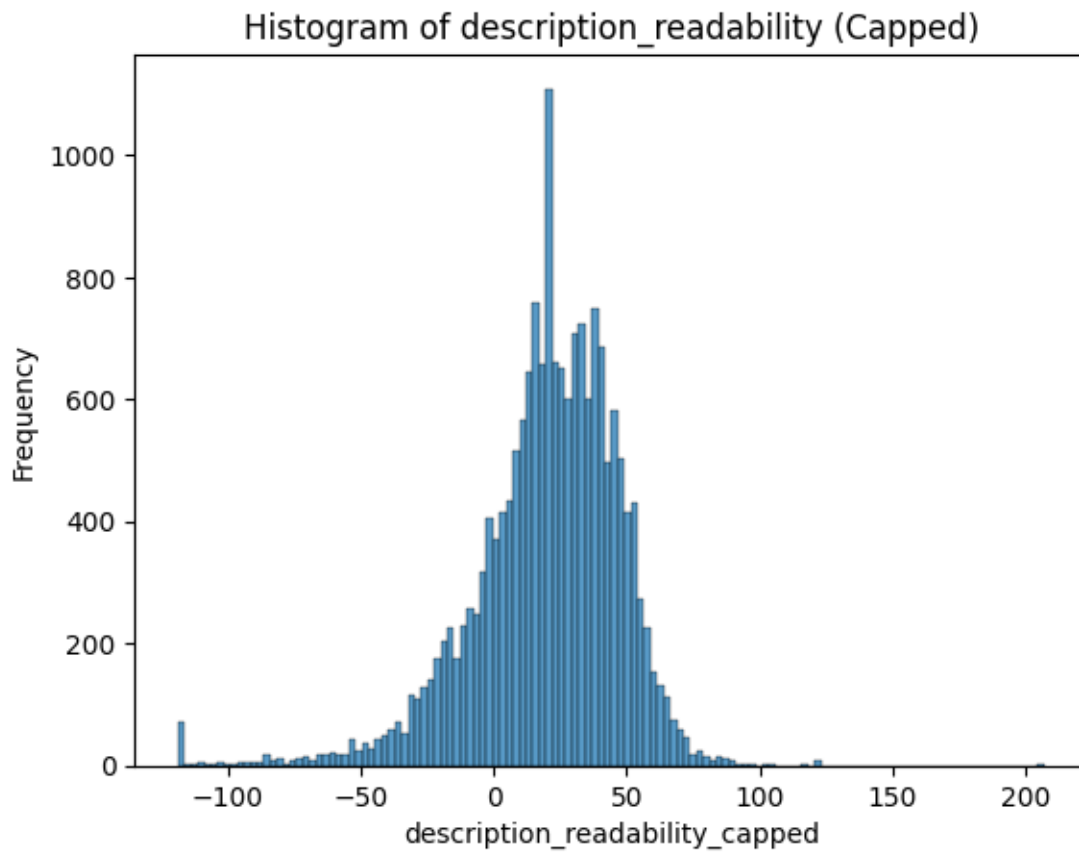
Purpose Since we have a number of outliers that could affect the results of some models, such as regression models, we will add additional features that cap values at the q1 and q3 values of each feature. We will review the histogram of each of the new capped features to ensure that the overall data is still consistent with the uncapped.

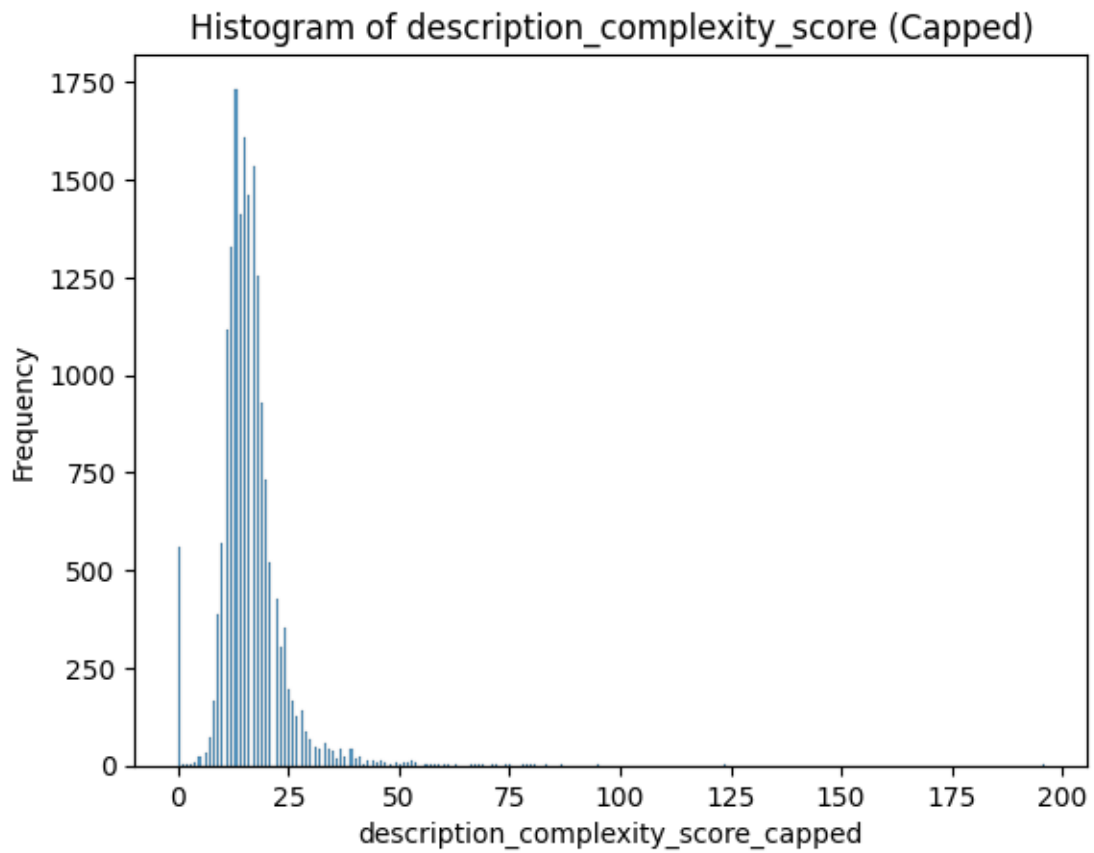
```
[ ]: for col in numeric_columns:
    q1 = cleaned_df['description_wordcount'].quantile(0.25)
    q3 = cleaned_df['description_wordcount'].quantile(0.75)
    iqr = q3 - q1
    lower_bound = q1 - 1.5 * iqr
    upper_bound = q3 + 1.5 * iqr
    cleaned_df[f'{col}_capped'] = cleaned_df[col].clip(lower=lower_bound,
    ↪upper=upper_bound)
    sns.histplot(data=cleaned_df, x=f'{col}_capped')
    plt.title(f'Histogram of {col} (Capped)')
    plt.xlabel(f'{col}_capped')
```

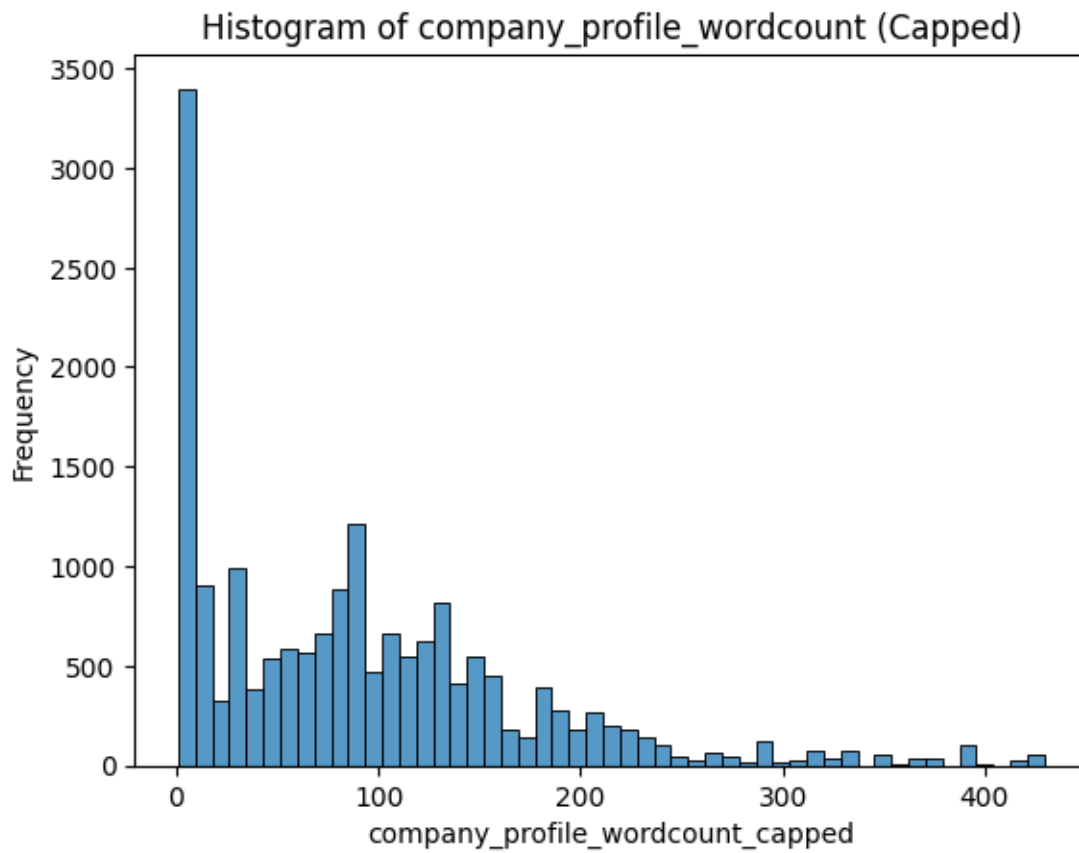


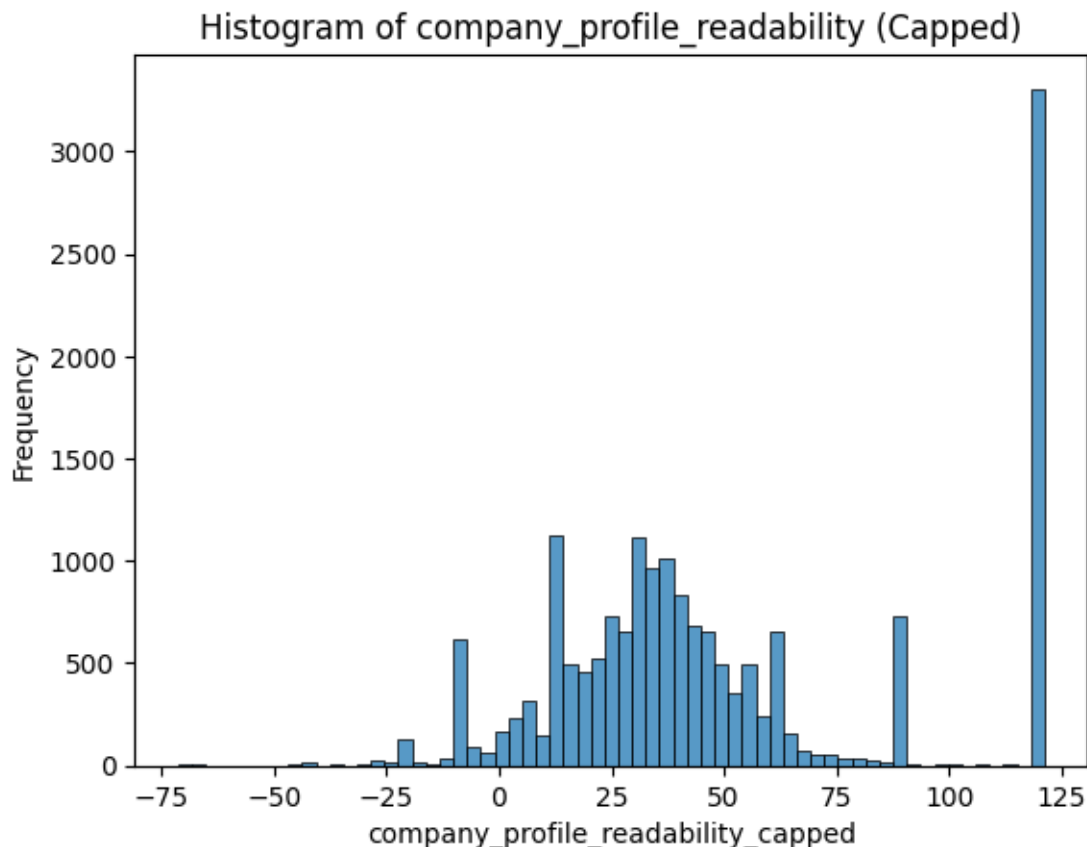
```
plt.ylabel('Frequency')  
plt.show()
```











Results As we can see, the histograms are still similarly shaped as the uncapped histograms with values more suitable for regression models. With models that are sensitive to outliers, we can use ‘description_wordcount_capped’, ‘description_readability_capped’, ‘description_complexity_score_capped’, ‘company_profile_wordcount_capped’, and ‘company_profile_readability_capped’. For models less sensitive to outliers, we can use the original data.

1.3.6 Data Exploratory Data Analysis Summary

Now that we have done a thorough analysis and exploration of our dataset, we are finally ready to start to apply models. We have deferred applying TF-IDF to our categorical features such as company_profile and description until we get to more advanced models.

2 Model Training and Evaluation

2.1 Environment Setup

2.2 Regression

2.2.1 Linear Regression - 2 Features

TODO: Identify two attributes in the consumable usage dataset and develop a linear regression model using the identified attributes and `sklearn.linear_model.LinearRegression`. Measure the performance of the model and make sure that the model performance is high. Draw a plot using matplotlib to show the observed and the predicted values.

Model Performance **TODO:** Report loss functions: mean squared error, root mean squared error, mean absolute error.

2.2.2 Linear Regression - More Than 2 Features

TODO: Identify more than two attributes in the consumable usage dataset and develop a multiple linear regression model using the identified attributes and `sklearn.linear_model.LinearRegression`. Measure the performance of the model and make sure that the model performance is high. Draw a plot using `mplot3d` to show the observed and the predicted values.

Model Performance Report loss functions: mean squared error, root mean squared error, mean absolute error.

2.2.3 Logistic Regression

TODO: Develop a logistic regression model among some identified attributes in the consumable usage dataset and `sklearn.linear_model.LogisticRegression`. Measure the performance of the model and make sure that the model performance is high. Draw a plot using matplotlib to show the observed and the predicted values.

Model Performance Report: absolute loss, log loss

2.2.4 Regression Summary

2.3 Evaluating Model Performance

2.3.1 Cross-Validation

TODO: Apply cross-validation techniques (at least one) in each of the above cases, and compare the results with simple train-test splits.

2.3.2 Bootstrap Method

TODO: Apply bootstrap method to one of the models and report the error mean and standard deviation.

2.3.3 Model Comparison

TODO: Compare models using one-standard-error or adjusted-R-squared methods, and report.

2.3.4 Model Performance Summary

TODO: Add a conclusion text cell and summarize your work and what you learned.

3 Supervised And Unsupervised Learning:

3.1 Supervised Learning:

Supervised Learning: Choose one of the supervised learning algorithms from K-nearest Neighbors, Naive Bayes, Support Vector Machine, and apply on the consumables usage, showing the effectiveness of the algorithm.

4 Step 0: Import needed python modules and setup logging:

4.1 Purpose:

We need these modules to build our model.

```
[1]: import os
import logging
from typing import List
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
from pathlib import Path
import seaborn as sns

import re
from nltk.corpus import stopwords
from nltk.tokenize import word_tokenize
from nltk.stem import WordNetLemmatizer

import nltk
nltk.download('punkt')
nltk.download('punkt_tab')
nltk.download('stopwords')
nltk.download('wordnet')
nltk.download('omw-1.4')

from sklearn.feature_extraction.text import TfidfVectorizer
from sklearn.preprocessing import OneHotEncoder
from sklearn.model_selection import train_test_split
from scipy.sparse import hstack, csr_matrix

from imblearn.over_sampling import SMOTE
from scipy.sparse import issparse
from imblearn.over_sampling import RandomOverSampler
```

```
import xgboost as xgb
from sklearn.metrics import classification_report, roc_auc_score

# Setup logging
logging.basicConfig(level=logging.INFO)
logger = logging.getLogger(__name__)
```

```
[nltk_data] Downloading package punkt to C:\Users\joshi\nltk_data...
[nltk_data]   Package punkt is already up-to-date!
[nltk_data] Downloading package punkt_tab to
[nltk_data]   C:\Users\joshi\nltk_data...
[nltk_data]   Package punkt_tab is already up-to-date!
[nltk_data] Downloading package stopwords to
[nltk_data]   C:\Users\joshi\nltk_data...
[nltk_data]   Package stopwords is already up-to-date!
[nltk_data] Downloading package wordnet to C:\Users\joshi\nltk_data...
[nltk_data]   Package wordnet is already up-to-date!
[nltk_data] Downloading package omw-1.4 to C:\Users\joshi\nltk_data...
[nltk_data]   Package omw-1.4 is already up-to-date!
```

```
[ ]: cleaned_df = pd.read_csv(r'C:\Users\Projects.
    ↪RealFakeJobPredictor\ml\EDA\data\cleaned_job_postings.csv')

cleaned_df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
```

```
RangeIndex: 17880 entries, 0 to 17879
```

```
Data columns (total 14 columns):
```

#	Column	Non-Null Count	Dtype
0	job_id	17880 non-null	int64
1	title	17880 non-null	object
2	description	17879 non-null	object
3	requirements	15184 non-null	object
4	company_profile	14572 non-null	object
5	employment_type	17880 non-null	object
6	telecommuting	17880 non-null	int64
7	fraudulent	17880 non-null	int64
8	description_wordcount	17880 non-null	int64
9	description_readability	17880 non-null	float64
10	description_complexity_score	17880 non-null	float64
11	company_profile_wordcount	17880 non-null	int64
12	company_profile_readability	17880 non-null	float64
13	company_profile_complexity_score	17880 non-null	float64

```
dtypes: float64(4), int64(5), object(5)
```

```
memory usage: 1.9+ MB
```


4.2 Result: All modules were loaded successfully.

5 Step 1: Select Relevant Columns

6 Step 2: Clean and Preprocess Text

6.1 Purpose:

We start by identifying the columns that will be used as inputs (features) and the target (label). This includes: - **Textual features** (job title, description, etc.) - **Structured features** (employment type, telecommuting, etc.) - **Engineered features** (word count, readability, etc.) - The **target column** (**fraudulent**) is the label we want to predict (0 = real job, 1 = fake job). This step defines the scope of the modeling pipeline.

Textual data often contains noise like punctuation, case variation, stopwords, etc. Cleaning transforms it into a standard format suitable for modeling.

We: - Convert to lowercase - Remove punctuation and short/informative words - Tokenize and lemmatize - Remove stopwords

This ensures cleaner token input to the TF-IDF vectorizer in Step 3.

```
[5]: text_columns = ["title", "description", "requirements", "company_profile"]
    structured_columns = [
        "employment_type", "telecommuting",
        "description_wordcount", "description_readability",
        ↪ "description_complexity_score",
        "company_profile_wordcount", "company_profile_readability",
        ↪ "company_profile_complexity_score"
    ]
    target_column = "fraudulent"

    stop_words = set(stopwords.words('english'))
    lemmatizer = WordNetLemmatizer()

    def clean_text(text):
        if not isinstance(text, str) or text.strip() == "":
            return ""
        text = text.lower()
        text = re.sub(r"[^a-z\s]", "", text)
        tokens = word_tokenize(text)
        tokens = [lemmatizer.lemmatize(w) for w in tokens if w not in stop_words
        ↪ and len(w) > 2]
        return " ".join(tokens)

    for col in text_columns:
        cleaned_df[f"{col}_cleaned"] = cleaned_df[col].fillna("").apply(clean_text)
```

```
cleaned_df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 17880 entries, 0 to 17879
Data columns (total 18 columns):
 #   Column                                Non-Null Count  Dtype
---  -
 0   job_id                               17880 non-null  int64
 1   title                                17880 non-null  object
 2   description                           17879 non-null  object
 3   requirements                          15184 non-null  object
 4   company_profile                      14572 non-null  object
 5   employment_type                      17880 non-null  object
 6   telecommuting                       17880 non-null  int64
 7   fraudulent                           17880 non-null  int64
 8   description_wordcount                 17880 non-null  int64
 9   description_readability                17880 non-null  float64
10  description_complexity_score           17880 non-null  float64
11  company_profile_wordcount              17880 non-null  int64
12  company_profile_readability            17880 non-null  float64
13  company_profile_complexity_score       17880 non-null  float64
14  title_cleaned                         17880 non-null  object
15  description_cleaned                   17880 non-null  object
16  requirements_cleaned                  17880 non-null  object
17  company_profile_cleaned                17880 non-null  object
dtypes: float64(4), int64(5), object(9)
memory usage: 2.5+ MB
```

6.2 Result:

Text, structured, and engineered features are defined, and the target column is clearly identified for downstream processing.

Four cleaned text columns (*_cleaned) are created with uniform structure and reduced noise, ready for vectorization.

7 Step 3: TF-IDF Vectorization

7.1 Purpose:

TF-IDF (Term Frequency-Inverse Document Frequency) converts the cleaned text into numerical feature vectors, capturing the importance of words in each document. Each text field (title, description, etc.) is vectorized separately and limited to a maximum number of features to control dimensionality.

```
[6]: from sklearn.feature_extraction.text import TfidfVectorizer
     from scipy.sparse import hstack

     def vectorize_columns(df, cols, max_features=3000):
```

```

matrices = []
vectorizers = {}
for col in cols:
    vect = TfidfVectorizer(max_features=max_features)
    matrix = vect.fit_transform(df[col])
    matrices.append(matrix)
    vectorizers[col] = vect
return hstack(matrices), vectorizers

X_tfidf, tfidf_vectorizers = vectorize_columns(cleaned_df, [f"{col}_cleaned"
↪for col in text_columns], max_features=3000)

```

7.2 Result:

Sparse TF-IDF matrices are generated and horizontally stacked, creating a high-dimensional text representation suitable for model input.

8 Step 4: Encode Categorical and Numeric Features

8.1 Purpose:

To incorporate structured data: - Categorical columns (employment type) are one-hot encoded - Numerical columns (readability scores) are used as is

Both are combined with TF-IDF vectors to build a unified feature matrix representing each job posting.

```

[8]: from sklearn.preprocessing import OneHotEncoder
from scipy.sparse import csr_matrix

encoder = OneHotEncoder(handle_unknown='ignore')
X_cat = encoder.fit_transform(cleaned_df[["employment_type"]])

X_numeric = csr_matrix(cleaned_df[
    ["telecommuting", "description_wordcount", "description_readability",
     "description_complexity_score", "company_profile_wordcount",
     "company_profile_readability", "company_profile_complexity_score"]
].fillna(0).astype(float).values)

X_full = hstack([X_tfidf, X_cat, X_numeric])
y = cleaned_df[target_column].astype(int).values

```

8.2 Result:

A full sparse matrix (X_full) is created by combining TF-IDF, categorical encodings, and numeric features. This matrix is now ready for training/test splitting.

9 Step 5: Train/Test Split with Stratification

9.1 Purpose:

We split the data into training and testing sets while preserving the fraud/non-fraud class distribution using stratification. This ensures that performance metrics reflect real-world class imbalance.

```
[9]: from sklearn.model_selection import train_test_split

X_train, X_test, y_train, y_test = train_test_split(X_full, y, test_size=0.2,
↪stratify=y, random_state=42)
```

9.2 Result:

The dataset is split into `X_train`, `X_test`, `y_train`, and `y_test`, each preserving the original class ratio.

10 Step 6: Dimensionality Reduction with TruncatedSVD

10.1 Purpose:

TF-IDF vectors are high-dimensional and sparse, which increases model complexity and training time.

TruncatedSVD reduces these vectors to a lower-dimensional dense representation (300 components), while preserving important variance in the data.

```
[10]: from sklearn.decomposition import TruncatedSVD

svd = TruncatedSVD(n_components=300, random_state=42)
X_train_reduced = svd.fit_transform(X_train)
X_test_reduced = svd.transform(X_test)
```

10.2 Result:

Both training and test feature matrices are reduced in dimensionality using the same fitted SVD transformer.

11 Step 7: Apply SMOTE

11.1 Purpose:

SMOTE (Synthetic Minority Oversampling Technique) is used to balance the training dataset by generating synthetic examples of the minority class (fraudulent jobs).

This prevents the model from being biased toward the majority class (real jobs).

```
[11]: from imblearn.over_sampling import SMOTE

smote = SMOTE(random_state=42)
```

```
X_train_resampled, y_train_resampled = smote.fit_resample(X_train_reduced,   
↪y_train)
```

11.2 Result:

The training data (`X_train_reduced`) is oversampled, resulting in a balanced training set (`X_train_resampled`) with equal real and fake jobs.

12 Step 8: Train XGBoost Model

12.1 Purpose:

We train an XGBoost classifier using the oversampled training data. XGBoost is chosen for its strong performance on tabular data, robustness to multicollinearity, and support for early stopping.

Early stopping prevents overfitting by halting training once validation performance stops improving.

```
[ ]: import xgboost as xgb

dtrain = xgb.DMatrix(X_train_resampled, label=y_train_resampled)
dtest = xgb.DMatrix(X_test_reduced, label=y_test)

params = {
    "objective": "binary:logistic",
    "eval_metric": "auc",
    "learning_rate": 0.05,
    "max_depth": 6,
    "seed": 42
}

booster = xgb.train(
    params,
    dtrain,
    num_boost_round=500,
    evals=[(dtest, "validation")],
    early_stopping_rounds=10,
    verbose_eval=True
)
```

12.2 Result:

An optimized XGBoost model (`booster`) is trained using the SMOTE-balanced, SVD-reduced training set.

It's ready for evaluation.

13 Step 9: Evaluate Model

13.0.1 Purpose

We evaluate the model on the untouched test set using several metrics:

- Classification report: Precision, recall, F1 per class
- ROC-AUC: Overall ranking ability
- Confusion matrix: Counts of true/false positives/negatives
- Accuracy, precision, recall, F1, and ROC-AUC: Summary stats

This gives a full picture of performance and error types.

```
[ ]: from sklearn.metrics import classification_report, confusion_matrix, \
      ↪roc_auc_score, accuracy_score, precision_score, recall_score, f1_score
import matplotlib.pyplot as plt
import seaborn as sns

# Predict probabilities and class labels:
y_pred_proba = booster.predict(dtest)
y_pred = (y_pred_proba >= 0.5).astype(int)

# Classification report:
print("Classification Report:\n", classification_report(y_test, y_pred, \
      ↪zero_division=0))

# ROC-AUC:
roc_auc = roc_auc_score(y_test, y_pred_proba)
print("ROC-AUC:", roc_auc)

# Confusion matrix plot:
cm = confusion_matrix(y_test, y_pred)
sns.heatmap(cm, annot=True, fmt="d", cmap="Blues", xticklabels=["Real", \
      ↪"Fake"], yticklabels=["Real", "Fake"])
plt.xlabel("Predicted")
plt.ylabel("Actual")
plt.title("Confusion Matrix")
plt.show()

# Evaluation summary:
accuracy = accuracy_score(y_test, y_pred)
precision = precision_score(y_test, y_pred, zero_division=0)
recall = recall_score(y_test, y_pred, zero_division=0)
f1 = f1_score(y_test, y_pred, zero_division=0)

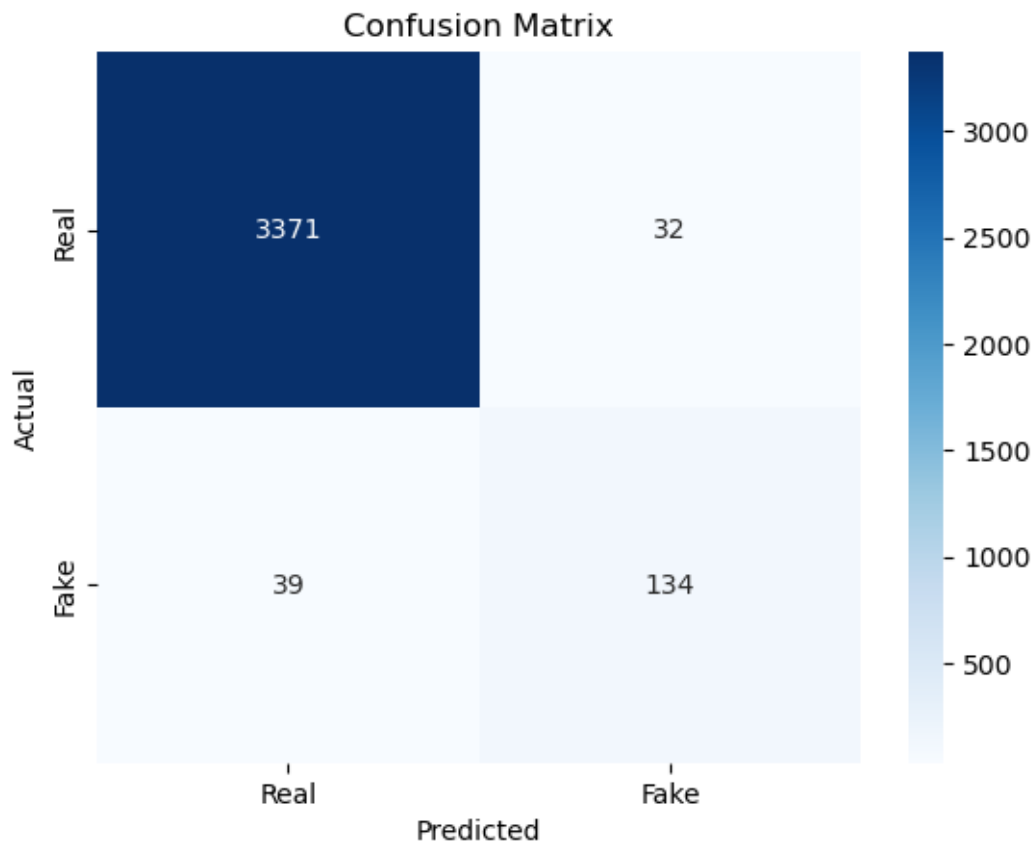
print("\nEvaluation Summary:")
print(f"Accuracy:  {accuracy:.4f}")
print(f"Precision: {precision:.4f}")
print(f"Recall:    {recall:.4f}")
```

```
print(f"F1 Score: {f1:.4f}")
print(f"ROC-AUC: {roc_auc:.4f}")
```

Classification Report:

	precision	recall	f1-score	support
0	0.99	0.99	0.99	3403
1	0.81	0.77	0.79	173
accuracy			0.98	3576
macro avg	0.90	0.88	0.89	3576
weighted avg	0.98	0.98	0.98	3576

ROC-AUC: 0.9852459322698943



Evaluation Summary:

Accuracy: 0.9801
Precision: 0.8072
Recall: 0.7746
F1 Score: 0.7906

ROC-AUC: 0.9852

13.1 Result:

The model achieves strong classification metrics (high precision and recall for fraud detection) and the confusion matrix shows low misclassification rates.

14 Final Results:

The model demonstrates strong performance in detecting fake job postings on the unseen test set. Below is a breakdown of each evaluation output.

14.0.1 Classification Report:

Class	Precision	Recall	F1-score	Support
0 (Real)	0.99	0.99	0.99	3403
1 (Fake)	0.81	0.77	0.79	173

- **Precision (Fake = 1):** 0.81 (Of all jobs predicted as fake, 81% were actually fake. This indicates a low false positive rate.)
- **Recall (Fake = 1):** 0.77 (Of all actual fake jobs, 77% were correctly identified. The model misses some, but it catches most.)
- **F1 Score (Fake = 1):** 0.79 (A strong balance between precision and recall for the fraud class.)

14.1 ROC-AUC Score:

- **ROC-AUC: 0.9852** (This shows the model's ability to distinguish between real and fake jobs across thresholds.)

A near-perfect score (> 0.98) suggests the model ranks fake jobs very well.

14.2 Confusion Matrix:

	Predicted Real (0)	Predicted Fake (1)
Actual Real (0)	3371 (True Negatives)	32 (False Positives)
Actual Fake (1)	39 (False Negatives)	134 (True Positives)

- **True Negatives (3371):** Real jobs correctly classified as real.
- **True Positives (134):** Fake jobs correctly classified as fake.
- **False Positives (32):** Real jobs incorrectly flagged as fake, small error, indicates high precision.
- **False Negatives (39):** Fake jobs incorrectly missed as real, relatively low, indicating strong recall.

14.3 Evaluation Summary:

- **Accuracy:** 98.01% -> Nearly all jobs correctly classified overall.
- **Precision:** 80.72% -> Model is highly confident when predicting fraud.
- **Recall:** 77.46% -> Model captures the majority of fake listings.
- **F1 Score:** 79.06% -> Balanced performance on minority class.
- **ROC-AUC:** 98.52% -> Excellent ranking ability, top-tier model confidence.

14.4 Conclusion:

The model effectively detects fake job postings with minimal false alarms, strong ranking ability, and a great trade-off between precision and recall.

These results indicate that the pipeline is suitable for real-world deployment or as a decision support system for fraud analysts.

15 Unsupervised Learning

Unsupervised Learning: Choose one of the unsupervised learning algorithms from K-means clustering or hierarchical Clustering, and apply on the consumables usage dataset, showing the effectiveness of the algorithm.

16 Step 1: Load and Prepare Data

16.1 Purpose:

The goal of this step is to load the cleaned job postings dataset and prepare it for unsupervised learning.

Since unsupervised models do not use labels during training, we separate the target column (`fraudulent`) from the rest of the dataset.

We retain the target values (`y_true`) solely for **evaluation purposes after modeling**.

The feature matrix (`X_unsupervised`) excludes any label or target information to maintain the integrity of an unsupervised setup.

```
[ ]: def load_and_prepare_unsupervised_data(filepath: str, target_column: str = 'fraudulent') -> tuple[pd.DataFrame, pd.Series]:  
    """  
    Load the job postings dataset and prepare it for unsupervised learning.  
  
    Args:  
        filepath (str): Path to the CSV file.  
        target_column (str): Name of the target column to exclude from features.  
  
    Returns:  
        tuple: (features_df, target_series)  
        - features_df: DataFrame without the target column.  
        - target_series: The target labels (for evaluation only).
```

```

"""
try:
    df = pd.read_csv(filepath)
    logger.info(f"Dataset loaded successfully with shape: {df.shape}")
except Exception as e:
    logger.error(f"Error loading dataset from {filepath}: {e}")
    raise

if target_column not in df.columns:
    raise ValueError(f"Target column '{target_column}' not found in dataset.
↪")

# Log columns and class balance (for evaluation only):
logger.info(f"Columns in dataset: {df.columns.tolist()}")
logger.info(f"Target distribution:\n{df[target_column].value_counts()}")

# Separate features and target:
X = df.drop(columns=[target_column])
y = df[target_column]

logger.info(f"Prepared features with shape: {X.shape}")
return X, y

# Example usage
file_path = r'C:
↪\Users\joshi\OneDrive\MainFolder_Darshan_Joshi\Angelo_State_University_ASU\CS-6330-REPO\Pro
↪RealFakeJobPredictor\ml\EDA\data\cleaned_job_postings.csv'

X_unsupervised, y_true = load_and_prepare_unsupervised_data(file_path)

# # Optional: Peek at the data
# print(X_unsupervised.head())
# # For evaluation only
# print(y_true.value_counts())

```

```

INFO:__main__:Dataset loaded successfully with shape: (17880, 14)
INFO:__main__:Columns in dataset: ['job_id', 'title', 'description',
'requirements', 'company_profile', 'employment_type', 'telecommuting',
'fraudulent', 'description_wordcount', 'description_readability',
'description_complexity_score', 'company_profile_wordcount',
'company_profile_readability', 'company_profile_complexity_score']
INFO:__main__:Target distribution:
fraudulent
0      17014
1       866
Name: count, dtype: int64
INFO:__main__:Prepared features with shape: (17880, 13)

```

16.2 Result:

The dataset was successfully loaded, and the `fraudulent` column was separated.

The features in `X_unsupervised` are now ready for preprocessing, and `y_true` will be used later to measure how well the model identifies fraudulent jobs.

- Shape of `X_unsupervised`: Matches original dataset minus the label column.
- `y_true.value_counts()`: Provides class distribution, which is useful for understanding class imbalance.

17 Step 2: Preprocess Features (Text, Categorical, Numeric)

17.1 Purpose:

This step transforms the raw features into numerical format for modeling.

Since we're dealing with text, categorical, and engineered numeric fields, we process each type appropriately:

- Text fields (`title`, `description`, etc.) are vectorized using **TF-IDF**, which converts them into high-dimensional sparse numerical representations capturing word importance.
- Categorical fields like `employment_type` and `telecommuting` are transformed using **One-Hot Encoding**.
- Engineered numeric fields such as readability and complexity scores are used as-is.

All feature types are then combined into a single sparse matrix suitable for dimensionality reduction and anomaly detection.

```
[ ]: def preprocess_features(X: pd.DataFrame) -> tuple:
    """
    Preprocess features for unsupervised modeling:
    - TF-IDF on text fields
    - One-Hot Encoding on categorical/boolean fields
    - Keep numeric engineered features as-is

    Args:
        X (pd.DataFrame): Feature dataframe

    Returns:
        tuple: (X_transformed (scipy.sparse matrix), fitted vectorizers)
    """
    try:
        logger.info("Starting preprocessing...")

        # 1. Separate features:
        text_fields = ['title', 'description', 'requirements', ↵
        ↵ 'company_profile']
        categorical_fields = ['employment_type', 'telecommuting']
```

```

        numeric_fields = [col for col in X.columns if 'wordcount' in col or
↳ 'readability' in col or 'complexity' in col]

    # 2. TF-IDF Vectorization:
    tfidf = TfidfVectorizer(max_features=3000, stop_words='english')
    combined_text = X[text_fields].fillna('').agg(' '.join, axis=1)
    X_tfidf = tfidf.fit_transform(combined_text)
    logger.info(f"TF-IDF shape: {X_tfidf.shape}")

    # 3. One-Hot Encode Categorical Fields:
    ohe = OneHotEncoder(handle_unknown='ignore')
    X_categorical = ohe.fit_transform(X[categorical_fields]).
↳ fillna('missing'))
    logger.info(f"One-hot encoded categorical shape: {X_categorical.shape}")

    # 4. Numeric Features (keep as dense matrix):
    X_numeric = X[numeric_fields].fillna(0).astype(float).values
    logger.info(f"Numeric shape: {X_numeric.shape}")

    # 5. Combine all:
    from scipy.sparse import csr_matrix
    X_combined = hstack([X_tfidf, X_categorical, csr_matrix(X_numeric)])
    logger.info(f"Final combined feature matrix shape: {X_combined.shape}")

    return X_combined, tfidf, ohe

except Exception as e:
    logger.error(f"Error during preprocessing: {e}")
    raise

X_transformed, tfidf_vectorizer, ohe_encoder =
↳ preprocess_features(X_unsupervised)

```

```

INFO:__main__:Starting preprocessing..
INFO:__main__:TF-IDF shape: (17880, 3000)
INFO:__main__:One-hot encoded categorical shape: (17880, 8)
INFO:__main__:Numeric shape: (17880, 6)
INFO:__main__:Final combined feature matrix shape: (17880, 3014)

```

17.2 Result:

- TF-IDF transformed text data into a sparse matrix of shape (n_samples, 3000)
- One-hot encoded categorical fields into binary columns
- Numeric engineered features retained as dense arrays
- Final combined feature matrix (X_transformed) has a shape indicating total feature dimensionality and is now ready for dimensionality reduction

18 Step 3: Dimensionality Reduction with Truncated SVD

18.1 Purpose:

High-dimensional feature spaces (especially from TF-IDF) can be noisy, redundant, and computationally expensive.

This step applies **Truncated Singular Value Decomposition (SVD)** to reduce dimensionality while preserving the structure of the data.

This not only speeds up training but also helps unsupervised algorithms like Isolation Forest by reducing noise and focusing on the most important underlying patterns in the data.

```
[12]: from sklearn.decomposition import TruncatedSVD

def apply_truncated_svd(X_sparse, n_components: int = 100, random_state: int = 42) -> tuple:
    """
    Applies TruncatedSVD to reduce the dimensionality of sparse features.

    Args:
        X_sparse (scipy.sparse matrix): Combined sparse feature matrix
        n_components (int): Number of components to keep
        random_state (int): For reproducibility

    Returns:
        tuple: (X_reduced (np.ndarray), svd_model)
    """
    try:
        logger.info(f"Reducing dimensionality to {n_components} components using TruncatedSVD...")
        svd = TruncatedSVD(n_components=n_components, random_state=random_state)
        X_reduced = svd.fit_transform(X_sparse)
        logger.info(f"Reduced shape: {X_reduced.shape}")
        return X_reduced, svd

    except Exception as e:
        logger.error(f"Error applying Truncated SVD: {e}")
        raise

X_reduced, svd_model = apply_truncated_svd(X_transformed, n_components=150)
```

```
INFO:__main__:Reducing dimensionality to 150 components using TruncatedSVD...
```

```
INFO:__main__:Reduced shape: (17880, 150)
```

18.2 Result:

The sparse input matrix was reduced to 150 components using TruncatedSVD.

The resulting array (`X_reduced`) is a dense 2D matrix of shape (`n_samples`, 150) and is now

suitable for use with distance- or tree-based anomaly detection methods.

Dimensionality was successfully reduced while retaining meaningful variance in the dataset.

19 Step 4: Train Isolation Forest

19.1 Purpose:

This step trains an **Isolation Forest**, an unsupervised anomaly detection algorithm that identifies rare or unusual patterns in the data by isolating points in a decision tree ensemble.

The assumption is that fake job postings are outliers or anomalies and will be easier to isolate. We estimate the expected fraction of frauds via the `contamination` parameter (set to 5%).

The model outputs anomaly scores and binary predictions (-1 for anomalies, 1 for normal).

```
[22]: from sklearn.ensemble import IsolationForest

def train_isolation_forest(X: np.ndarray, contamination: float = 0.05,
    random_state: int = 42) -> tuple:
    """
    Train Isolation Forest to detect anomalies in job postings.

    Args:
        X (np.ndarray): Feature matrix (after SVD)
        contamination (float): Estimated proportion of outliers
        random_state (int): For reproducibility

    Returns:
        tuple: (model, anomaly_scores, predictions)
    """
    try:
        logger.info("Training Isolation Forest...")
        iso_forest = IsolationForest(
            n_estimators=100,
            contamination=contamination,
            random_state=random_state,
            verbose=0
        )
        iso_forest.fit(X)
        scores = iso_forest.decision_function(X) # The higher, the more normal
        predictions = iso_forest.predict(X)      # -1 = anomaly, 1 = normal
        logger.info(f"Isolation Forest training complete. Anomalies found:
    {(predictions == -1).sum()}")
        return iso_forest, scores, predictions
    except Exception as e:
        logger.error(f"Error training Isolation Forest: {e}")
        raise
```

```
# You can tweak contamination depending on how many outliers you expect
model, anomaly_scores, anomaly_labels = train_isolation_forest(X_reduced,
↳contamination=0.05)
```

```
# Optional preview
print(pd.Series(anomaly_labels).value_counts())
```

```
INFO:__main__:Training Isolation Forest...
```

```
INFO:__main__:Isolation Forest training complete. Anomalies found: 894
```

```
1      16986
```

```
-1       894
```

```
Name: count, dtype: int64
```

19.2 Result:

The Isolation Forest model was trained successfully. Predictions (`anomaly_labels`) were generated, with -1 indicating anomalies and 1 indicating normal jobs.

A quick value count of the predictions shows how many jobs were flagged as suspicious (anomalous) by the model. These predictions will now be compared against the actual `fraudulent` labels.

20 Step 5: Evaluate Against fraudulent Labels

20.1 Purpose:

This step evaluates how well the unsupervised model (which has never seen the labels) was able to identify actual fake jobs.

We convert -1 predictions from Isolation Forest into 1 (fraud prediction) and compare them against the truth (`y_true`).

We calculate and visualize: - A **confusion matrix** - **Precision, recall, F1-score** for both real and fraud classes - **Overall accuracy, macro F1, and ROC-AUC**

These metrics provide a quantitative view of the model's effectiveness at flagging frauds.

```
[ ]: from sklearn.metrics import classification_report, confusion_matrix,
↳roc_auc_score

def evaluate_unsupervised_predictions(anomaly_labels: np.ndarray, y_true: pd.
↳Series) -> dict:
    """
    Evaluate how well the anomaly predictions match the actual fraudulent
↳labels,
    and print a confusion matrix and classification metrics in a readable
↳format.

    Args:
```

```

    anomaly_labels (np.ndarray): Predictions from Isolation Forest (-1 =
↪ anomaly)
    y_true (pd.Series): Actual labels (0 = real, 1 = fraudulent)

Returns:
    dict: Contains confusion matrix, classification report, and ROC-AUC
↪ score
    """
    try:
        logger.info("Evaluating anomaly predictions against true fraud labels...
↪ ")

        # Map -1 to 1 (fraud guess), 1 to 0 (real guess):
        predicted_fraud = (anomaly_labels == -1).astype(int)

        # Compute metrics:
        cm = confusion_matrix(y_true, predicted_fraud)
        cr = classification_report(y_true, predicted_fraud, output_dict=True)
        roc_auc = roc_auc_score(y_true, predicted_fraud)

        # Plot confusion matrix:
        plt.figure(figsize=(6, 4))
        sns.heatmap(cm, annot=True, fmt='d', cmap='Blues',
                    xticklabels=['Predicted Real', 'Predicted Fraud'],
                    yticklabels=['Actual Real', 'Actual Fraud'])
        plt.title('Confusion Matrix')
        plt.xlabel('Predicted Label')
        plt.ylabel('Actual Label')
        plt.tight_layout()
        plt.show()

        # Print clean classification metrics:
        print("\nClassification Report:")
        print(f"{'Class':<15}{'Precision':>10}{'Recall':>10}{'F1-Score':
↪ >10}{'Support':>10}")
        for label in ['0', '1']:
            metrics = cr[label]
            print(f"{label:<15}{metrics['precision']:10.4f}{metrics['recall']:
↪ 10.4f}"
                  f"{metrics['f1-score']:10.4f}{metrics['support']:10.0f}")

        print("\nOverall Metrics:")
        print(f"{'Accuracy':<15}{cr['accuracy']:10.4f}")
        print(f"{'ROC-AUC':<15}{roc_auc:10.4f}")
        print(f"{'Macro F1-Score':<15}{cr['macro avg']['f1-score']:10.4f}")

        return {

```



```

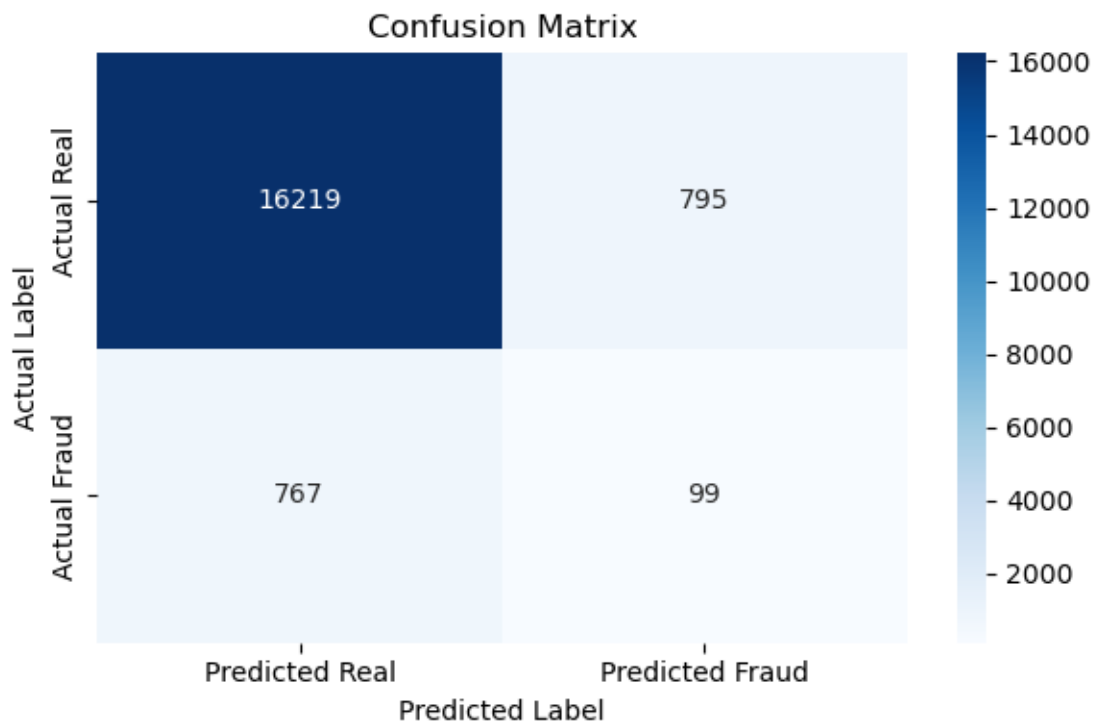
        "confusion_matrix": cm,
        "classification_report": cr,
        "roc_auc": roc_auc
    }

    except Exception as e:
        logger.error(f"Evaluation error: {e}")
        raise

results = evaluate_unsupervised_predictions(anomaly_labels, y_true)

```

INFO:__main__:Evaluating anomaly predictions against true fraud labels...



Classification Report:

Class	Precision	Recall	F1-Score	Support
0	0.9548	0.9533	0.9541	17014
1	0.1107	0.1143	0.1125	866

Overall Metrics:

Accuracy	0.9126
ROC-AUC	0.5338
Macro F1-Score	0.5333

20.2 Result:

- The confusion matrix shows the number of true positives (correctly flagged frauds), false positives (real jobs flagged as fraud), false negatives (missed frauds), and true negatives.
- Precision and recall for class 1 (fraudulent) were both low (~11%), meaning the model struggles to find most frauds and produces false positives.
- Accuracy is high (~91%) but misleading due to class imbalance.
- ROC-AUC score of ~0.53 indicates the model performs just slightly better than random guessing for fraud detection.

This tells us the model needs tuning or a different approach to better identify fraudulent postings.

21 Supervised & Unsupervised Learning Conclusion:

21.1 Comparison of Supervised and Unsupervised Fraud Detection on Job Postings:

This notebook presents a comparison between two modeling approaches for detecting fake job postings: 1. **Supervised Learning** using XGBoost 2. **Unsupervised Learning** using Isolation Forest

21.2 Problem Context:

The dataset consists of real and fraudulent job postings, with the goal of detecting fake ones based on various features: - **Textual**: title, description, requirements, company_profile - **Categorical**: employment_type, telecommuting - **Engineered features**: word count, readability, and complexity scores

Both approaches leverage identical feature engineering and preprocessing steps to ensure comparability.

The `fraudulent` column is used for evaluation **only** in the unsupervised approach.

21.3 Supervised Learning Summary (XGBoost):

21.3.1 Pipeline Highlights

- **Model**: XGBoost Classifier
- **Preprocessing**:
 - TF-IDF vectorization of text fields
 - TruncatedSVD to 300 components
 - One-hot encoding for categorical variables
 - Numeric features used as-is
- **Train/Test Split**: 80/20 stratified
- **Imbalance Handling**: SMOTE oversampling on minority class
- **Optimization**: Early stopping enabled
- **Target**: `fraudulent` (0 = real, 1 = fake)

21.3.2 Performance on Test Set:

Classification Report:

Class	Precision	Recall	F1-score	Support
0 (Real)	0.99	0.99	0.99	3403
1 (Fake)	0.81	0.77	0.79	173

Confusion Matrix:

	Predicted Real (0)	Predicted Fake (1)
Actual Real	3371	32
Actual Fake	39	134

Key Metrics:

- **Accuracy:** 98.01%
- **Precision (fraud):** 80.72%
- **Recall (fraud):** 77.46%
- **F1 Score (fraud):** 79.06%
- **ROC-AUC:** 0.9852

21.3.3 Conclusion:

The supervised XGBoost model performed exceptionally well, achieving great separation between real and fake jobs.

High ROC-AUC and F1 indicate strong generalization with minimal false alarms.

It may be well-suited as a fraud detection engine.

21.4 Unsupervised Learning Summary (Isolation Forest):

21.4.1 Pipeline Highlights

- **Model:** Isolation Forest
- **Contamination:** 0.05 (estimated fraud prevalence)
- **Preprocessing:**
 - Same text/categorical/numeric pipeline
 - TruncatedSVD to 150 components (reduced to minimize noise)
- **Target:** Not used during training; **fraudulent** used only for evaluation

21.4.2 Evaluation vs fraudulent Label:

Confusion Matrix:

	Predicted Real (0)	Predicted Fraud (1)
Actual Real	16,219	795
Actual Fraud	767	99

Classification Report:

Class	Precision	Recall	F1-score	Support
0 (Real)	0.9548	0.9533	0.9541	17014
1 (Fraud)	0.1107	0.1143	0.1125	866

Key Metrics:

- **Accuracy:** 91.26% (inflated by class imbalance)
- **ROC-AUC:** 0.5338 (barely better than random)
- **F1 Score (fraud):** 0.1125

21.4.3 Conclusion:

The Isolation Forest model struggled to detect fraud effectively. While it correctly classified most real jobs, it missed 89% of frauds and frequently flagged real jobs as fake.

The low ROC-AUC and F1 score for class 1 indicate weak anomaly detection performance with the current feature set.

21.5 Final Comparison Summary:

Aspect	Supervised (XGBoost)	Unsupervised (Isolation Forest)
Model Objective	Predict fraud w/ labels	Detect fraud as anomalies
Labels Used	Yes	No (only for eval)
Accuracy	98.01%	91.26% (misleading due to imbalance)
F1 Score (fraud)	0.79	0.11
ROC-AUC	0.9852	0.5338
Missed frauds (FN)	39	767
False alarms (FP)	32	795

21.6 Final Thoughts:

- **Supervised learning** vastly outperforms unsupervised learning in this case, thanks to access to labeled data and balanced training via SMOTE.
- **Unsupervised anomaly detection** is useful in early-stage detection when no labels exist, but its performance is much weaker for fraud tasks with subtle signals.

Future work for Unsupervised learning - Try Alternative Models: - One-Class SVM: Good for separating dense vs sparse regions. - **DBSCAN:** Detects dense clusters and isolates noise (good if frauds are isolated).