PROJECT - **Unsupervised Anamoly Detection**

DATASET - **Healthcare Providers Data For Anomaly Detection**

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Overview

Healthcare fraud is considered a challenge for many societies. Health care funding that could be spent on medicine, care for the elderly, or emergency room visits is instead lost to fraudulent activities by materialistic practitioners or patients. With rising healthcare costs, healthcare fraud is a major contributor to these increasing healthcare costs.

In [1]:
```
# Filtering the warnings
import warnings
warnings.filterwarnings("ignore")
```

Data Loading

In [2]:
```
import pandas as pd

# Loading the dataset
df = pd.read_csv("Healthcare Providers.csv")
```

Milestone 1: Exploratory Data Analysis (EDA)

1. Exploratory Data Analysis

1.1 Initial Exploration

In [3]:
```
# Display the first few rows of the dataset
df.head()
```

Out[3]:

	index	National Provider Identifier	Last Name/Organization Name of the Provider	First Name of the Provider	Middle Initial of the Provider	Credentials of the Provider	Gender of the Provider	Entity Type of the Provider	Street Address 1 of the Provider	Street Address 2 of the Provider	...	H
0	8774979	1891106191	UPADHYAYULA	SATYASREE	NaN	M.D.	F	I	1402 S GRAND BLVD	FDT 14TH FLOOR	...	
1	3354385	1346202256	JONES	WENDY	P	M.D.	F	I	2950 VILLAGE DR	NaN	...	
2	3001884	1306820956	DUROCHER	RICHARD	W	DPM	M	I	20 WASHINGTON AVE	STE 212	...	
3	7594822	1770523540	FULLARD	JASPER	NaN	MD	M	I	5746 N BROADWAY ST	NaN	...	
4	746159	1073627758	PERROTTI	ANTHONY	E	DO	M	I	875 MILITARY TRL	SUITE 200	...	

5 rows × 27 columns

Inference: We have loaded the dataset and displayed the first few rows to get an initial look at the data.

1.2 Checking the Shape and Missing Values

In [4]:
```
# Check the shape of the dataset
df.shape
```

Out[4]: (100000, 27)

In [5]:
```
# Check for missing values
df.isnull().sum()
```

Out[5]:
```
index                                                        0
National Provider Identifier                                 0
Last Name/Organization Name of the Provider                  0
First Name of the Provider                                4255
Middle Initial of the Provider                           29331
Credentials of the Provider                               7209
Gender of the Provider                                    4254
Entity Type of the Provider                                  0
Street Address 1 of the Provider                             0
Street Address 2 of the Provider                         59363
City of the Provider                                         0
Zip Code of the Provider                                     0
State Code of the Provider                                   0
Country Code of the Provider                                 0
Provider Type                                                0
Medicare Participation Indicator                             0
Place of Service                                             0
HCPCS Code                                                   0
HCPCS Description                                            0
HCPCS Drug Indicator                                         0
Number of Services                                           0
Number of Medicare Beneficiaries                             0
Number of Distinct Medicare Beneficiary/Per Day Services     0
Average Medicare Allowed Amount                              0
Average Submitted Charge Amount                              0
Average Medicare Payment Amount                              0
Average Medicare Standardized Amount                         0
dtype: int64
```

Inference: This helps us understand the size of the dataset and identify columns with missing values.

1.3 Summary Statistics and Information

In [6]:
```
# Summary statistics of the dataset
df.describe()
```

Out[6]:

	index	National Provider Identifier	Zip Code of the Provider
count	1.000000e+05	1.000000e+05	1.000000e+05
mean	4.907646e+06	1.498227e+09	4.163820e+08
std	2.839633e+06	2.874125e+08	3.082566e+08
min	2.090000e+02	1.003001e+09	6.010000e+02
25%	2.458791e+06	1.245669e+09	1.426300e+08
50%	4.901266e+06	1.497847e+09	3.633025e+08
75%	7.349450e+06	1.740374e+09	6.819881e+08
max	9.847440e+06	1.993000e+09	9.990166e+08

In [7]:
```
# Information about the dataset
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 100000 entries, 0 to 99999
Data columns (total 27 columns):
 #   Column                                                Non-Null Count   Dtype  
---  ------                                                --------------   -----  
 0   index                                                 100000 non-null  int64  
 1   National Provider Identifier                          100000 non-null  int64  
 2   Last Name/Organization Name of the Provider           100000 non-null  object 
 3   First Name of the Provider                            95745 non-null   object 
 4   Middle Initial of the Provider                        70669 non-null   object 
 5   Credentials of the Provider                           92791 non-null   object 
 6   Gender of the Provider                                95746 non-null   object 
 7   Entity Type of the Provider                           100000 non-null  object 
 8   Street Address 1 of the Provider                      100000 non-null  object 
 9   Street Address 2 of the Provider                      40637 non-null   object 
 10  City of the Provider                                  100000 non-null  object 
 11  Zip Code of the Provider                              100000 non-null  float64
 12  State Code of the Provider                            100000 non-null  object 
 13  Country Code of the Provider                          100000 non-null  object 
 14  Provider Type                                         100000 non-null  object 
 15  Medicare Participation Indicator                      100000 non-null  object 
 16  Place of Service                                      100000 non-null  object 
 17  HCPCS Code                                            100000 non-null  object 
 18  HCPCS Description                                     100000 non-null  object 
 19  HCPCS Drug Indicator                                  100000 non-null  object 
 20  Number of Services                                    100000 non-null  object 
 21  Number of Medicare Beneficiaries                      100000 non-null  object 
 22  Number of Distinct Medicare Beneficiary/Per Day Services  100000 non-null  object 
 23  Average Medicare Allowed Amount                       100000 non-null  object 
 24  Average Submitted Charge Amount                       100000 non-null  object 
 25  Average Medicare Payment Amount                       100000 non-null  object 
 26  Average Medicare Standardized Amount                  100000 non-null  object 
dtypes: float64(1), int64(2), object(24)
memory usage: 20.6+ MB
```

Inference: describe() provides insights into the central tendency, dispersion, and shape of the dataset's distribution. info() helps us understand the data types and non-null values.

In [8]:
```
import numpy as np
import seaborn as sns
import matplotlib.pyplot as plt
```

2: Data Preprocessing

2.1 Merging columns

In [9]:
```
# Merging the name columns into a single column
df['Full Name'] = df['First Name of the Provider'].fillna('') + ' ' + \
                  df['Middle Initial of the Provider'].fillna('') + ' ' + \
                  df['Last Name/Organization Name of the Provider'].fillna('')
df['Full Name'] = df['Full Name'].str.strip()

df = df.drop(columns=['Last Name/Organization Name of the Provider',
                      'First Name of the Provider',
                      'Middle Initial of the Provider'])

full_name = df.pop('Full Name')

df.insert(1, 'Full Name', full_name)


df.head()
```

Out[9]:

	index	Full Name	National Provider Identifier	Credentials of the Provider	Gender of the Provider	Entity Type of the Provider	Street Address 1 of the Provider	Street Address 2 of the Provider	City of the Provider	Zip Code of the Provider	...
0	8774979	SATYASREE UPADHYAYULA	1891106191	M.D.	F	I	1402 S GRAND BLVD	FDT 14TH FLOOR	SAINT LOUIS	631041004.0	...
1	3354385	WENDY P JONES	1346202256	M.D.	F	I	2950 VILLAGE DR	NaN	FAYETTEVILLE	283043815.0	...
2	3001884	RICHARD W DUROCHER	1306820956	DPM	M	I	20 WASHINGTON AVE	STE 212	NORTH HAVEN	64732343.0	...
3	7594822	JASPER FULLARD	1770523540	MD	M	I	5746 N BROADWAY ST	NaN	KANSAS CITY	641183998.0	...
4	746159	ANTHONY E PERROTTI	1073627758	DO	M	I	875 MILITARY TRL	SUITE 200	JUPITER	334585700.0	...

5 rows × 25 columns

In [10]:
```
# Dropping columns which are not needed
DropColumns = ['Entity Type of the Provider',
               'Street Address 1 of the Provider',
               'Street Address 2 of the Provider',
               'Medicare Participation Indicator',
               'Place of Service',
               'HCPCS Code',
               'HCPCS Description',
               'HCPCS Drug Indicator',
               'Country Code of the Provider']
df = df.drop(DropColumns, axis=1)

df.head()
```

Out[10]:

	index	Full Name	National Provider Identifier	Credentials of the Provider	Gender of the Provider	City of the Provider	Zip Code of the Provider	State Code of the Provider	Provider Type	Number of Services	Nu M Bene
0	8774979	SATYASREE UPADHYAYULA	1891106191	M.D.	F	SAINT LOUIS	631041004.0	MO	Internal Medicine	27	
1	3354385	WENDY P JONES	1346202256	M.D.	F	FAYETTEVILLE	283043815.0	NC	Obstetrics & Gynecology	175	
2	3001884	RICHARD W DUROCHER	1306820956	DPM	M	NORTH HAVEN	64732343.0	CT	Podiatry	32	
3	7594822	JASPER FULLARD	1770523540	MD	M	KANSAS CITY	641183998.0	MO	Internal Medicine	20	
4	746159	ANTHONY E PERROTTI	1073627758	DO	M	JUPITER	334585700.0	FL	Internal Medicine	33	

2.2 Data Cleaning

In [11]:
```
# Cleaning 'Credentials of the Provider' Column: Removing periods '.' if present
df['Credentials of the Provider'] = df['Credentials of the Provider'].str.replace('.', '')
```

In [12]:
```
# Removing 'Zip Code of the Provider' column as it was evenly distributed (Observed during EDA)
df.drop(columns=['Zip Code of the Provider'], inplace=True)
```

In [13]:
```
df.head()
```

Out[13]:

	index	Full Name	National Provider Identifier	Credentials of the Provider	Gender of the Provider	City of the Provider	State Code of the Provider	Provider Type	Number of Services	Number of Medicare Beneficiaries	Ben Da
0	8774979	SATYASREE UPADHYAYULA	1891106191	MD	F	SAINT LOUIS	MO	Internal Medicine	27	24	
1	3354385	WENDY P JONES	1346202256	MD	F	FAYETTEVILLE	NC	Obstetrics & Gynecology	175	175	
2	3001884	RICHARD W DUROCHER	1306820956	DPM	M	NORTH HAVEN	CT	Podiatry	32	13	
3	7594822	JASPER FULLARD	1770523540	MD	M	KANSAS CITY	MO	Internal Medicine	20	18	
4	746159	ANTHONY E PERROTTI	1073627758	DO	M	JUPITER	FL	Internal Medicine	33	24	

Inference: Cleaned the 'Credentials of the Provider' column and removed the 'Zip Code of the Provider' column based on observations from EDA.

In [14]:
```
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 100000 entries, 0 to 99999
Data columns (total 15 columns):
 #   Column                                                 Non-Null Count   Dtype
---  ------                                                 --------------   -----
 0   index                                                  100000 non-null  int64
 1   Full Name                                              100000 non-null  object
 2   National Provider Identifier                           100000 non-null  int64
 3   Credentials of the Provider                            92791 non-null   object
 4   Gender of the Provider                                 95746 non-null   object
 5   City of the Provider                                   100000 non-null  object
 6   State Code of the Provider                             100000 non-null  object
 7   Provider Type                                          100000 non-null  object
 8   Number of Services                                     100000 non-null  object
 9   Number of Medicare Beneficiaries                       100000 non-null  object
 10  Number of Distinct Medicare Beneficiary/Per Day Services  100000 non-null  object
 11  Average Medicare Allowed Amount                        100000 non-null  object
 12  Average Submitted Charge Amount                        100000 non-null  object
 13  Average Medicare Payment Amount                        100000 non-null  object
 14  Average Medicare Standardized Amount                   100000 non-null  object
dtypes: int64(2), object(13)
memory usage: 11.4+ MB
```

2.3 Converting Numerical Columns

In [15]:
```
numeric_columns = [
    'Number of Services',
    'Number of Medicare Beneficiaries',
    'Number of Distinct Medicare Beneficiary/Per Day Services',
    'Average Medicare Allowed Amount',
    'Average Submitted Charge Amount',
    'Average Medicare Payment Amount',
    'Average Medicare Standardized Amount'
]

for column in numeric_columns:
    df[column] = pd.to_numeric(df[column], errors='coerce')


df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 100000 entries, 0 to 99999
Data columns (total 15 columns):
 #   Column                                                Non-Null Count   Dtype
---  ------                                                --------------   -----
 0   index                                                 100000 non-null  int64
 1   Full Name                                             100000 non-null  object
 2   National Provider Identifier                          100000 non-null  int64
 3   Credentials of the Provider                           92791 non-null   object
 4   Gender of the Provider                                95746 non-null   object
 5   City of the Provider                                  100000 non-null  object
 6   State Code of the Provider                            100000 non-null  object
 7   Provider Type                                         100000 non-null  object
 8   Number of Services                                    97347 non-null   float64
 9   Number of Medicare Beneficiaries                      99595 non-null   float64
 10  Number of Distinct Medicare Beneficiary/Per Day Services  98500 non-null  float64
 11  Average Medicare Allowed Amount                       99255 non-null   float64
 12  Average Submitted Charge Amount                       93277 non-null   float64
 13  Average Medicare Payment Amount                       99534 non-null   float64
 14  Average Medicare Standardized Amount                  99530 non-null   float64
dtypes: float64(7), int64(2), object(6)
memory usage: 11.4+ MB
```

2.4 Handling Missing Values

In [16]:
```
df.isnull().sum()
```

Out[16]:
```
index                                                    0
Full Name                                                0
National Provider Identifier                             0
Credentials of the Provider                           7209
Gender of the Provider                                4254
City of the Provider                                     0
State Code of the Provider                               0
Provider Type                                            0
Number of Services                                    2653
Number of Medicare Beneficiaries                       405
Number of Distinct Medicare Beneficiary/Per Day Services  1500
Average Medicare Allowed Amount                        745
Average Submitted Charge Amount                       6723
Average Medicare Payment Amount                        466
Average Medicare Standardized Amount                   470
dtype: int64
```

In [17]:
```
# Imputation of numeric missing values with mean
df[numeric_columns] = df[numeric_columns].fillna(df[numeric_columns].mean())

df.isnull().sum()
```

Out[17]:
```
index                                                    0
Full Name                                                0
National Provider Identifier                             0
Credentials of the Provider                           7209
Gender of the Provider                                4254
City of the Provider                                     0
State Code of the Provider                               0
Provider Type                                            0
Number of Services                                       0
Number of Medicare Beneficiaries                         0
Number of Distinct Medicare Beneficiary/Per Day Services       0
Average Medicare Allowed Amount                          0
Average Submitted Charge Amount                          0
Average Medicare Payment Amount                          0
Average Medicare Standardized Amount                     0
dtype: int64
```

In [18]:
```
# Imputation of categorical values with mode
df["Credentials of the Provider"] = df["Credentials of the Provider"].fillna(df["Credentials of the Provider"].
df["Gender of the Provider"] = df["Gender of the Provider"].fillna(df["Gender of the Provider"].mode()[0])
```

In [19]:
```
# Verify that there are no missing values left
df.isnull().sum()
```

Out[19]:
```
index                                                  0
Full Name                                              0
National Provider Identifier                           0
Credentials of the Provider                            0
Gender of the Provider                                 0
City of the Provider                                   0
State Code of the Provider                             0
Provider Type                                          0
Number of Services                                     0
Number of Medicare Beneficiaries                       0
Number of Distinct Medicare Beneficiary/Per Day Services    0
Average Medicare Allowed Amount                        0
Average Submitted Charge Amount                        0
Average Medicare Payment Amount                        0
Average Medicare Standardized Amount                   0
dtype: int64
```

Inference: We have dropped unnecessary columns and filled missing values in categorical columns with their mode (most frequent value).

2.5 Remove duplicates

In [20]:
```
df.duplicated().sum()
```

Out[20]:
```
0
```

In [21]:
```
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 100000 entries, 0 to 99999
Data columns (total 15 columns):
 #   Column                                                 Non-Null Count   Dtype
---  ------                                                 --------------   -----
 0   index                                                  100000 non-null  int64
 1   Full Name                                              100000 non-null  object
 2   National Provider Identifier                           100000 non-null  int64
 3   Credentials of the Provider                            100000 non-null  object
 4   Gender of the Provider                                 100000 non-null  object
 5   City of the Provider                                   100000 non-null  object
 6   State Code of the Provider                             100000 non-null  object
 7   Provider Type                                          100000 non-null  object
 8   Number of Services                                     100000 non-null  float64
 9   Number of Medicare Beneficiaries                       100000 non-null  float64
 10  Number of Distinct Medicare Beneficiary/Per Day Services  100000 non-null  float64
 11  Average Medicare Allowed Amount                        100000 non-null  float64
 12  Average Submitted Charge Amount                        100000 non-null  float64
 13  Average Medicare Payment Amount                        100000 non-null  float64
 14  Average Medicare Standardized Amount                   100000 non-null  float64
dtypes: float64(7), int64(2), object(6)
memory usage: 11.4+ MB
```

Inference: Converted numerical columns from strings with commas to numeric values.

2.5 Feature Engineering

In [22]:
```
# Adding new column as 'Ratio Medicare Payment to Submitted Charge'
df['Ratio Medicare Payment to Submitted Charge'] = df['Average Medicare Payment Amount'] / df['Average Submitte

df.head()
```

Out[22]:

	index	Full Name	National Provider Identifier	Credentials of the Provider	Gender of the Provider	City of the Provider	State Code of the Provider	Provider Type	Number of Services	Number of Medicare Beneficiaries	Bene Da
0	8774979	SATYASREE UPADHYAYULA	1891106191	MD	F	SAINT LOUIS	MO	Internal Medicine	27.0	24.0	
1	3354385	WENDY P JONES	1346202256	MD	F	FAYETTEVILLE	NC	Obstetrics & Gynecology	175.0	175.0	
2	3001884	RICHARD W DUROCHER	1306820956	DPM	M	NORTH HAVEN	CT	Podiatry	32.0	13.0	
3	7594822	JASPER FULLARD	1770523540	MD	M	KANSAS CITY	MO	Internal Medicine	20.0	18.0	
4	746159	ANTHONY E PERROTTI	1073627758	DO	M	JUPITER	FL	Internal Medicine	33.0	24.0	

Inference: Created a new feature 'Ratio Medicare Payment to Submitted Charge' to provide insights into the ratio of what Medicare pays versus what providers charge on average.

3: Encoding and Feature Scaling

3.1 One-hot Encoding

In [23]:
```
# Identify columns to be one-hot encoded
categorical_cols = [col for col in df.columns if df[col].dtype == 'O']
categorical_cols
```

Out[23]:
```
['Full Name',
 'Credentials of the Provider',
 'Gender of the Provider',
 'City of the Provider',
 'State Code of the Provider',
 'Provider Type']
```

In [24]:
```
# Perform one-hot encoding
df_one_hot = pd.get_dummies(df, columns=categorical_cols)
```

In [25]:
```
df_one_hot.head()
```

Out[25]:

	index	National Provider Identifier	Number of Services	Number of Medicare Beneficiaries	Number of Distinct Medicare Beneficiary/Per Day Services	Average Medicare Allowed Amount	Average Submitted Charge Amount	Average Medicare Payment Amount	Average Medicare Standardized Amount	Ratio Medicare Payment to Submitted Charge	...
0	8774979	1891106191	27.0	24.0	27.0	200.587778	305.211111	157.262222	160.908889	0.515257	...
1	3354385	1346202256	175.0	175.0	175.0	123.730000	548.800000	118.830000	135.315257	0.216527	...
2	3001884	1306820956	32.0	13.0	32.0	90.650000	155.000000	64.439688	60.595937	0.415740	...
3	7594822	1770523540	20.0	18.0	20.0	3.500000	5.000000	3.430000	3.430000	0.686000	...
4	746159	1073627758	33.0	24.0	31.0	26.520000	40.000000	19.539394	19.057576	0.488485	...

5 rows × 95014 columns

Inference: One-hot encoding converts categorical variables into a binary format, suitable for machine learning algorithms.

3.2 Binary Encoding

In [26]:
```
import category_encoders as ce

# Identify columns for binary encoding
BEcols = [var for var in df.columns if df[var].dtype == "O"]
BEcols
```

Out[26]:
```
['Full Name',
 'Credentials of the Provider',
 'Gender of the Provider',
 'City of the Provider',
 'State Code of the Provider',
 'Provider Type']
```

In [27]:
```
# Create a DataFrame for binary encoding
df_bin_enc = df.copy()
```

In [28]:
```
# Perform binary encoding
for col in BEcols:
    encoder = ce.BinaryEncoder(cols=[col])
    dfbin = encoder.fit_transform(df[col])
    df_bin_enc = pd.concat([df_bin_enc, dfbin], axis=1)
    df_bin_enc.drop(columns=[col], inplace=True)
```

In [29]:
```
df_bin_enc.head()
```

Out[29]:

	index	National Provider Identifier	Number of Services	Number of Medicare Beneficiaries	Number of Distinct Medicare Beneficiary/Per Day Services	Average Medicare Allowed Amount	Average Submitted Charge Amount	Average Medicare Payment Amount	Average Medicare Standardized Amount	Ratio Medicare Payment to Submitted Charge	...
0	8774979	1891106191	27.0	24.0	27.0	200.587778	305.211111	157.262222	160.908889	0.515257	...
1	3354385	1346202256	175.0	175.0	175.0	123.730000	548.800000	118.830000	135.315257	0.216527	...
2	3001884	1306820956	32.0	13.0	32.0	90.650000	155.000000	64.439688	60.595937	0.415740	...
3	7594822	1770523540	20.0	18.0	20.0	3.500000	5.000000	3.430000	3.430000	0.686000	...
4	746159	1073627758	33.0	24.0	31.0	26.520000	40.000000	19.539394	19.057576	0.488485	...

5 rows × 66 columns

Inference: Binary encoding reduces the number of columns compared to one-hot encoding, useful for categorical features with many unique values.

3.3 Frequency Encoding

In [30]:
```
# Identify columns for frequency encoding (assuming all categorical columns)
FEcols = [var for var in df.columns if df[var].dtype == "O"]
```

In [31]:
```
# Create a DataFrame for frequency encoding
df_freq_enc = df.copy()
```

In [32]:
```
# Perform frequency encoding
for col in FEcols:
    encoder = ce.CountEncoder(cols=[col])
    df_fe = encoder.fit_transform(df[col])
    df_freq_enc[col] = df_fe[col]
```

In [33]:
```
df_freq_enc.head()
```

Out[33]:

	index	Full Name	National Provider Identifier	Credentials of the Provider	Gender of the Provider	City of the Provider	State Code of the Provider	Provider Type	Number of Services	Number of Medicare Beneficiaries	Number of Distinct Medicare Beneficiary/Per Day Services	Ave Med All Am
0	8774979	1	1891106191	73827	29105	500	1997	11366	27.0	24.0	27.0	200.58
1	3354385	1	1346202256	73827	29105	209	3725	1028	175.0	175.0	175.0	123.73
2	3001884	1	1306820956	1915	70895	10	1403	2027	32.0	13.0	32.0	90.65
3	7594822	1	1770523540	73827	70895	317	1997	11366	20.0	18.0	20.0	3.50
4	746159	1	1073627758	6176	70895	51	7263	11366	33.0	24.0	31.0	26.52

Inference: Frequency encoding replaces categorical values with their frequency of occurrence, potentially capturing informative features for machine learning models.

4: Feature Scaling

4.1 Standardization

Standardizing Binary Encoded Data

In [34]:
```
from sklearn.preprocessing import StandardScaler

def Preprocessing(df_bin_enc):
    # Extract column names
    df_cols = df_bin_enc.columns

    # Instantiate StandardScaler
    std = StandardScaler()

    # Apply StandardScaler to numerical columns
    numeric_cols = df_bin_enc.select_dtypes(include=['float64', 'int64']).columns
    df_bin_enc[numeric_cols] = std.fit_transform(df_bin_enc[numeric_cols])

    return df_bin_enc
```

In [35]:
```
# Call the Preprocessing function for binary encoded data
df_bin_enc = Preprocessing(df_bin_enc)
```

In [36]:
```
df_bin_enc.head()
```

Out[36]:

	index	National Provider Identifier	Number of Services	Number of Medicare Beneficiaries	Number of Distinct Medicare Beneficiary/Per Day Services	Average Medicare Allowed Amount	Average Submitted Charge Amount	Average Medicare Payment Amount	Average Medicare Standardized Amount	Ratio Medicare Payment to Submitted Charge	...	Pro
0	1.361920	1.366960	-0.497577	-0.444753	-0.482232	1.098226	0.621012	0.972452	1.003321	0.219274	...	-1
1	-0.546996	-0.528945	0.503328	1.040098	0.554599	0.352134	1.940981	0.549955	0.722789	-0.466390	...	-1
2	-0.671133	-0.665966	-0.463762	-0.552921	-0.447204	0.031012	-0.192958	-0.047975	-0.096209	-0.009144	...	-1
3	0.946316	0.947412	-0.544917	-0.503753	-0.531272	-0.814992	-1.005784	-0.718674	-0.722804	0.611174	...	-1
4	-1.465509	-1.477323	-0.456999	-0.444753	-0.454210	-0.591527	-0.816125	-0.541578	-0.551510	0.157825	...	0

5 rows × 66 columns

Inference: Standardization transforms data to have a mean of 0 and a standard deviation of 1, making features comparable.

Standardizing Frequency Encoded Data

In [37]:
```
def Preprocessing(df_freq_enc):
    # Extract column names
    df_cols = df_freq_enc.columns

    # Instantiate StandardScaler
    std = StandardScaler()

    # Apply StandardScaler to numerical columns
    numeric_cols = df_freq_enc.select_dtypes(include=['float64', 'int64']).columns
    df_freq_enc[numeric_cols] = std.fit_transform(df_freq_enc[numeric_cols])

    return df_freq_enc
```

In [38]:
```
# Call the Preprocessing function for frequency encoded data
df_freq_enc = Preprocessing(df_freq_enc)
```

In [39]:
```
df_freq_enc.head()
```

Out[39]:

	index	Full Name	National Provider Identifier	Credentials of the Provider	Gender of the Provider	City of the Provider	State Code of the Provider	Provider Type	Number of Services	Number of Medicare Beneficiaries	Number of Distinct Medicare Beneficiary/Per Day Services
0	1.361920	-0.092857	1.366960	0.594983	-1.560716	1.571686	-0.737342	1.336743	-0.497577	-0.444753	-0.482232
1	-0.546996	-0.092857	-0.528945	0.594983	-1.560716	0.189180	-0.004973	-0.940500	0.503328	1.040098	0.554599
2	-0.671133	-0.092857	-0.665966	-1.684316	0.640731	-0.756245	-0.989093	-0.720441	-0.463762	-0.552921	-0.447204
3	0.946316	-0.092857	0.947412	0.594983	0.640731	0.702275	-0.737342	1.336743	-0.544917	-0.503753	-0.531272
4	-1.465509	-0.092857	-1.477323	-1.549260	0.640731	-0.561459	1.494517	1.336743	-0.456999	-0.444753	-0.454210

Inference: Standardization is applied similarly to frequency encoded data, ensuring consistent scaling across different encoding methods.

4.2 Normalization

Normalizing Binary Encoded Data

In [40]:
```
from sklearn.preprocessing import MinMaxScaler

def Preprocessing(df_bin_enc):
    # Extract column names
    df_cols = df_bin_enc.columns

    # Instantiate MinMaxScaler
    minmax_scaler = MinMaxScaler()

    # Apply MinMaxScaler to numerical columns
    numeric_cols = df_bin_enc.select_dtypes(include=['float64', 'int64']).columns
    df_bin_enc[numeric_cols] = minmax_scaler.fit_transform(df_bin_enc[numeric_cols])
```

```
    return df_bin_enc
```

In [41]:
```
# Call the Preprocessing function for binary encoded data
df_bin_enc = Preprocessing(df_bin_enc)
```

In [42]:
```
df_bin_enc.head()
```

Out[42]:

	index	National Provider Identifier	Number of Services	Number of Medicare Beneficiaries	Number of Distinct Medicare Beneficiary/Per Day Services	Average Medicare Allowed Amount	Average Submitted Charge Amount	Average Medicare Payment Amount	Average Medicare Standardized Amount	Ratio Medicare Payment to Submitted Charge	...	Co Provi
0	0.891090	0.897077	0.016194	0.013158	0.016194	0.200610	0.305285	0.157472	0.161099	0.098284	...	
1	0.340621	0.346668	0.165992	0.165992	0.165992	0.123740	0.548940	0.118987	0.135474	0.041261	...	
2	0.304824	0.306889	0.021255	0.002024	0.021255	0.090655	0.155032	0.064521	0.060662	0.079288	...	
3	0.771244	0.775276	0.009109	0.007085	0.009109	0.003491	0.004991	0.003426	0.003426	0.130876	...	
4	0.075752	0.071340	0.022267	0.013158	0.020243	0.026514	0.040001	0.019558	0.019072	0.093173	...	

5 rows × 66 columns

Inference: MinMax scaling transforms data to a [0, 1] range, preserving the relationships between data points while normalizing the features.

Normalizing Frequency Encoded Data

In [43]:
```
def Preprocessing(df_freq_enc):
    # Extract column names
    df_cols = df_freq_enc.columns

    # Instantiate MinMaxScaler
    minmax_scaler = MinMaxScaler()

    # Apply MinMaxScaler to numerical columns
    numeric_cols = df_freq_enc.select_dtypes(include=['float64', 'int64']).columns
    df_freq_enc[numeric_cols] = minmax_scaler.fit_transform(df_freq_enc[numeric_cols])

    return df_freq_enc
```

In [44]:
```
# Call the Preprocessing function for frequency encoded data
df_freq_enc = Preprocessing(df_freq_enc)
```

In [45]:
```
df_freq_enc.head()
```

Out[45]:

	index	Full Name	National Provider Identifier	Credentials of the Provider	Gender of the Provider	City of the Provider	State Code of the Provider	Provider Type	Number of Services	Number of Medicare Beneficiaries	Number of Distinct Medicare Beneficiary/Per Day Services	Averag Medica Allowe Amou
0	0.891090	0.0	0.897077	1.000000	0.0	0.470755	0.256753	0.906589	0.016194	0.013158	0.016194	0.20061
1	0.340621	0.0	0.346668	1.000000	0.0	0.196226	0.479033	0.081924	0.165992	0.165992	0.165992	0.12374
2	0.304824	0.0	0.306889	0.025926	1.0	0.008491	0.180345	0.161615	0.021255	0.002024	0.021255	0.09065
3	0.771244	0.0	0.775276	1.000000	1.0	0.298113	0.256753	0.906589	0.009109	0.007085	0.009109	0.00349
4	0.075752	0.0	0.071340	0.083643	1.0	0.047170	0.934139	0.906589	0.022267	0.013158	0.020243	0.02651

Inference: Normalization is applied similarly to frequency encoded data, ensuring features are scaled to a consistent range.

In [46]:
```
df_transformed = df_freq_enc
```

Milestone 3: ML Algorithms & SHAP Analysis

Anamoly Detection

In [47]:
```
anomaly_detection_columns = [
    'Number of Services',
    'Number of Medicare Beneficiaries',
    'Number of Distinct Medicare Beneficiary/Per Day Services',
    'Average Medicare Allowed Amount',
```

```
    'Average Submitted Charge Amount',
    'Average Medicare Payment Amount',
    'Average Medicare Standardized Amount',
    'Ratio Medicare Payment to Submitted Charge'
]

df_anamoly = df[anomaly_detection_columns]

df_anamoly.head()
```

Out[47]:

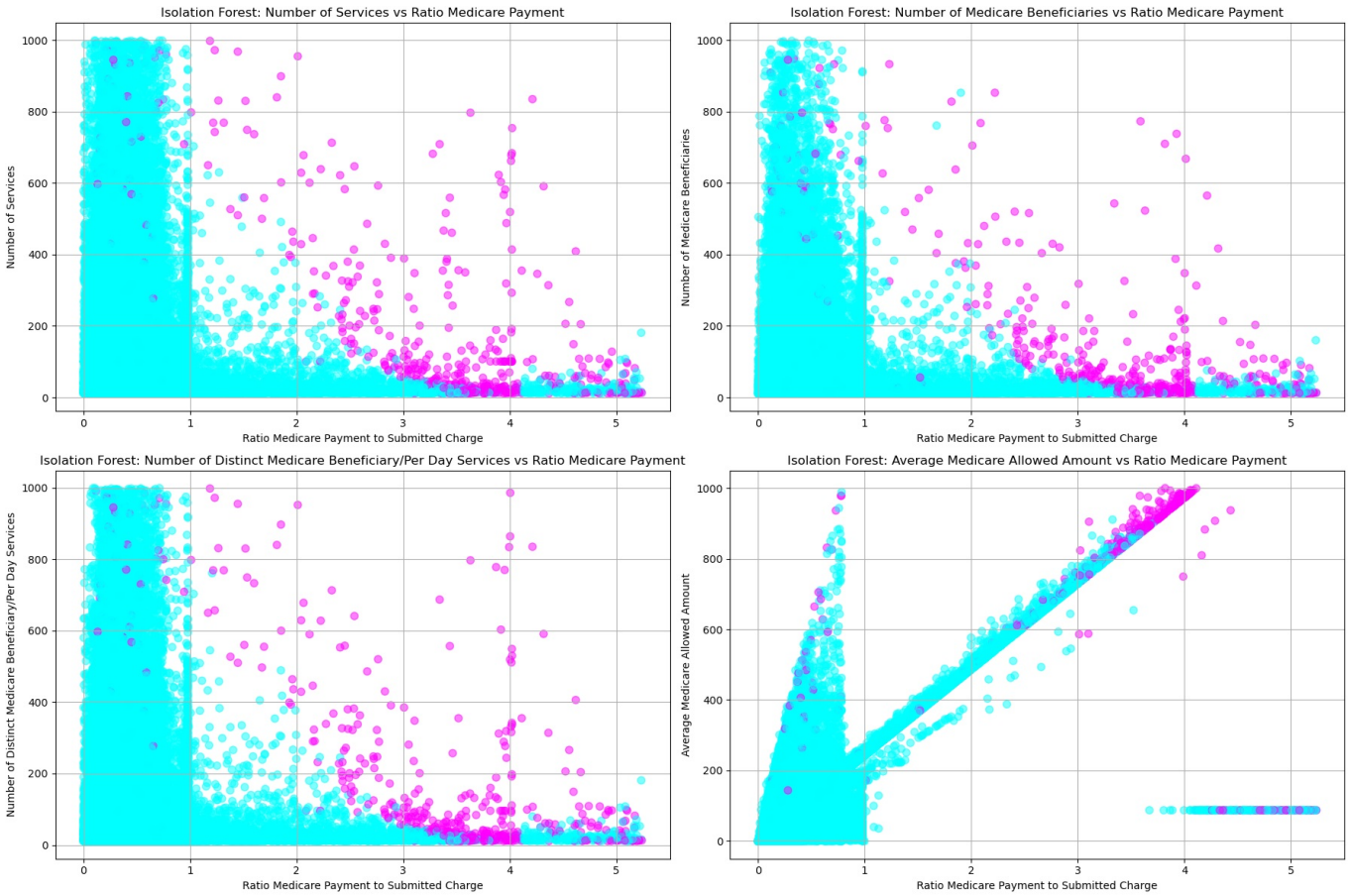
	Number of Services	Number of Medicare Beneficiaries	Number of Distinct Medicare Beneficiary/Per Day Services	Average Medicare Allowed Amount	Average Submitted Charge Amount	Average Medicare Payment Amount	Average Medicare Standardized Amount	Ratio Medicare Payment to Submitted Charge
0	27.0	24.0	27.0	200.587778	305.211111	157.262222	160.908889	0.515257
1	175.0	175.0	175.0	123.730000	548.800000	118.830000	135.315257	0.216527
2	32.0	13.0	32.0	90.650000	155.000000	64.439688	60.595937	0.415740
3	20.0	18.0	20.0	3.500000	5.000000	3.430000	3.430000	0.686000
4	33.0	24.0	31.0	26.520000	40.000000	19.539394	19.057576	0.488485

Isolation Forest

In [48]:
```
from sklearn.ensemble import IsolationForest

# Isolation Forest
isolation_forest = IsolationForest(contamination=0.005, random_state=42)
isolation_forest.fit(df_anamoly)
df_transformed['Anomaly_IF'] = isolation_forest.predict(df_anamoly)
df_transformed['Anomaly_IF'] = df_transformed['Anomaly_IF'].map({1: 0, -1: 1})
print("Isolation Forest anomalies detected:", df_transformed['Anomaly_IF'].sum())
```

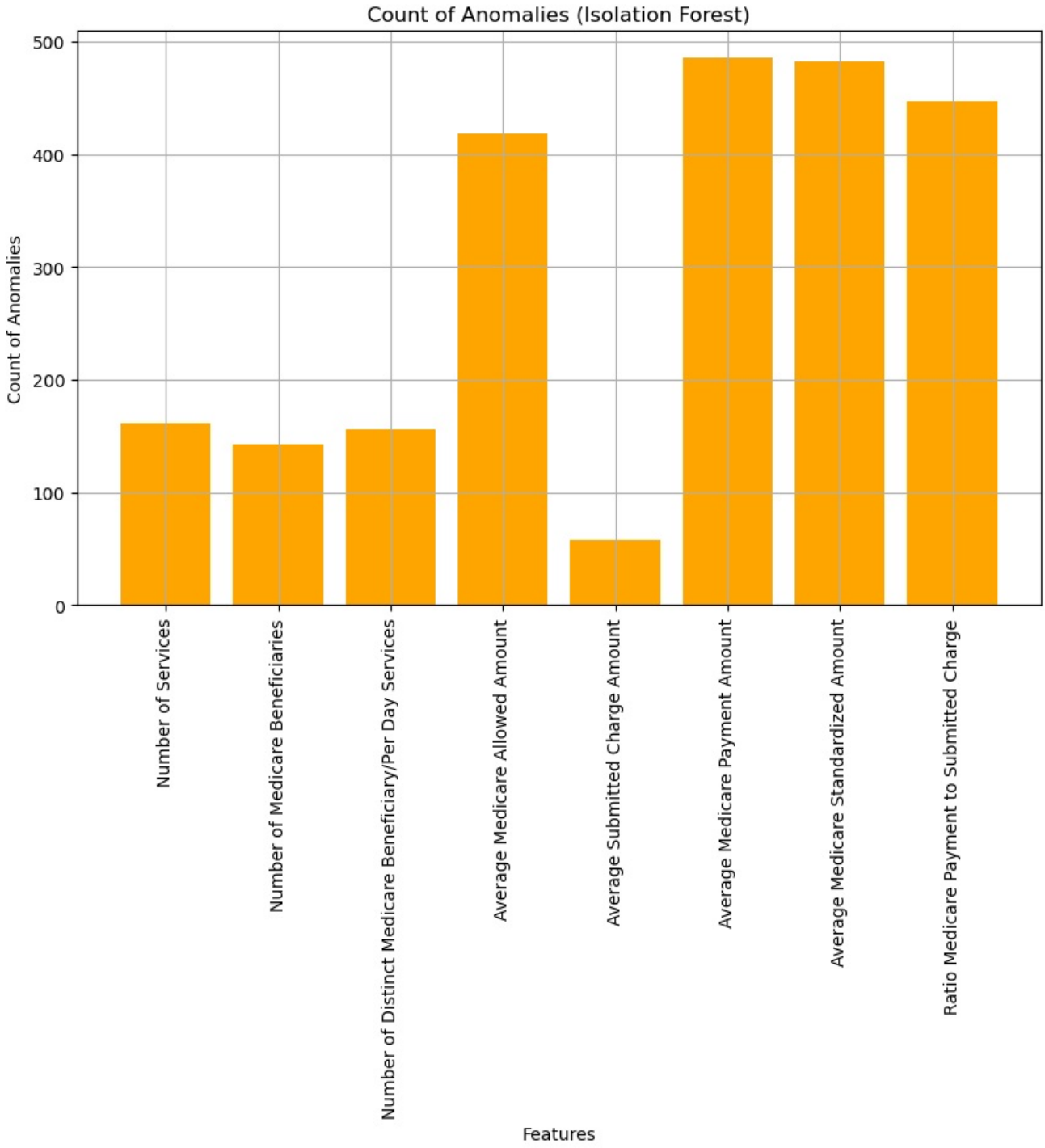
```
Isolation Forest anomalies detected: 500
```

In [49]:
```
# Scatter plots for Isolation Forest
plt.figure(figsize=(18, 12))
features = ['Number of Services', 'Number of Medicare Beneficiaries',
            'Number of Distinct Medicare Beneficiary/Per Day Services',
            'Average Medicare Allowed Amount']

for i, feature in enumerate(features):
    plt.subplot(2, 2, i + 1)
    plt.scatter(df_anamoly['Ratio Medicare Payment to Submitted Charge'], df_anamoly[feature],
                c=df_transformed['Anomaly_IF'], cmap='cool', s=50, alpha=0.5)
    plt.title(f'Isolation Forest: {feature} vs Ratio Medicare Payment')
    plt.xlabel('Ratio Medicare Payment to Submitted Charge')
    plt.ylabel(feature)
    plt.grid(True)

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



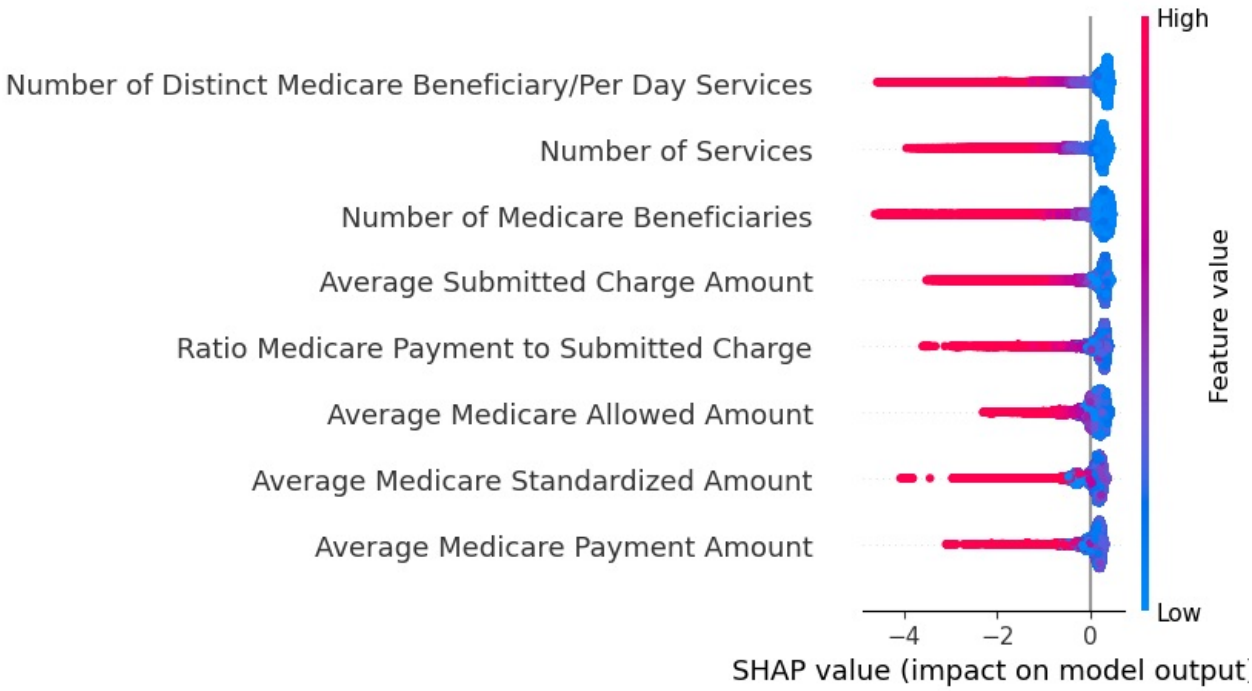
In [50]:
```python
# Define threshold
threshold = 1.5 * df_anamoly.std()

# Function to count anomalies for each feature
def count_anomalies(df_anamoly, threshold, anomalies):
    anomaly_counts = []
    for col in df_anamoly.columns:
        count = ((df_anamoly[col] > threshold[col]) & (anomalies == 1)).sum()
        anomaly_counts.append(count)
    return anomaly_counts
```

In [51]:
```python
anomaly_counts_if = count_anomalies(df_anamoly, threshold, df_transformed['Anomaly_IF'])

plt.figure(figsize=(10, 6))
plt.bar(df_anamoly.columns, anomaly_counts_if, color='orange')
plt.title('Count of Anomalies (Isolation Forest)')
plt.xlabel('Features')
plt.ylabel('Count of Anomalies')
plt.xticks(rotation=90)
plt.grid(True)
plt.show()
```



In [52]:
```
import shap

# SHAP analysis for Isolation Forest
explainer_if = shap.Explainer(isolation_forest, df_anamoly)
shap_values_if = explainer_if(df_anamoly)

# SHAP summary plot
shap.summary_plot(shap_values_if, df_anamoly)
```

```
100%|==================| 99999/100000 [11:31<00:00]
```

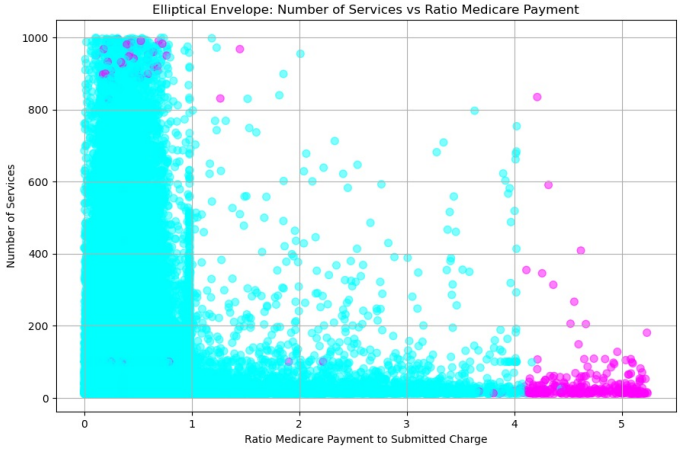


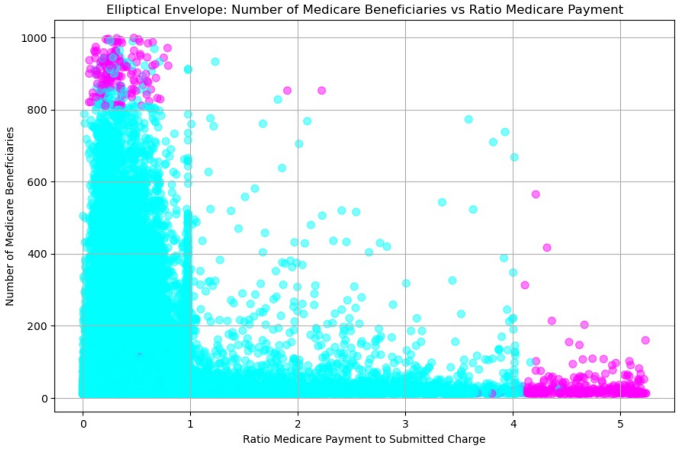
Elliptic Envelope

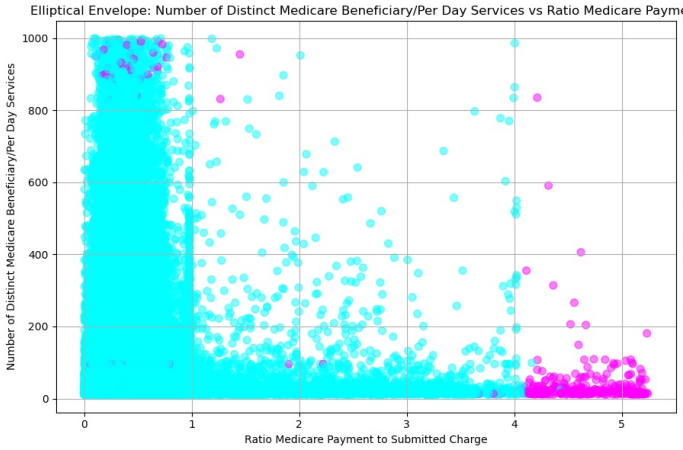
In [53]:
```
from sklearn.covariance import EllipticEnvelope

# Elliptic Envelope
elliptic_envelope = EllipticEnvelope(contamination=0.005, random_state=42)
elliptic_envelope.fit(df_anamoly)
df_transformed['Anomaly_EE'] = elliptic_envelope.predict(df_anamoly)
df_transformed['Anomaly_EE'] = df_transformed['Anomaly_EE'].map({1: 0, -1: 1})
print("Elliptic Envelope anomalies detected:", df_transformed['Anomaly_EE'].sum())
```

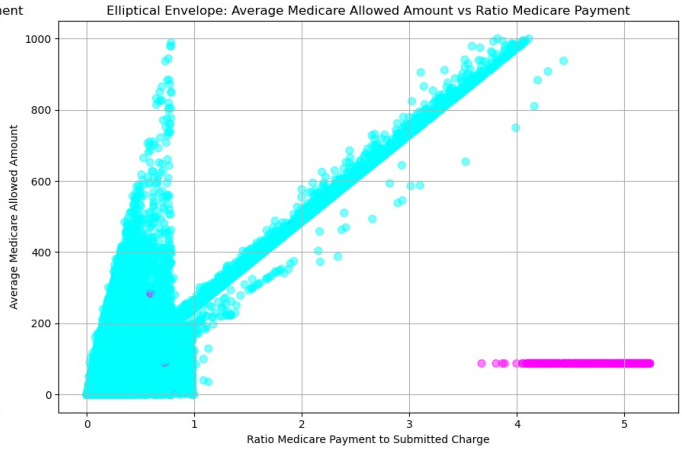
```
Elliptic Envelope anomalies detected: 500
```

In [54]:
```
# Scatter plots for Elliptical Envelope
plt.figure(figsize=(18, 12))

for i, feature in enumerate(features):
    plt.subplot(2, 2, i + 1)
    plt.scatter(df_anamoly['Ratio Medicare Payment to Submitted Charge'], df_anamoly[feature],
                c=df_transformed['Anomaly_EE'], cmap='cool', s=50, alpha=0.5)
    plt.title(f'Elliptical Envelope: {feature} vs Ratio Medicare Payment')
    plt.xlabel('Ratio Medicare Payment to Submitted Charge')
    plt.ylabel(feature)
    plt.grid(True)

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

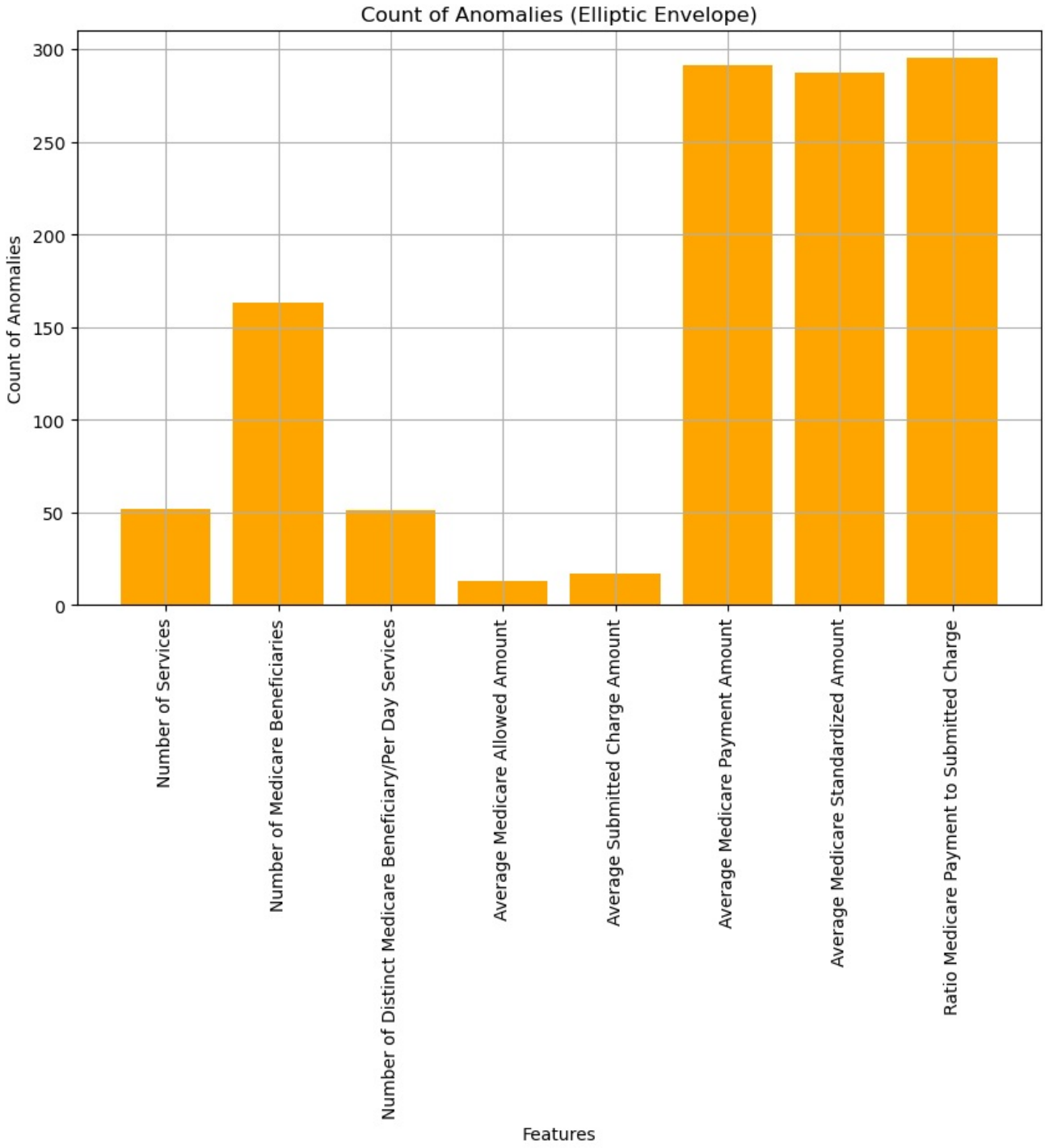








In [55]:
```
anomaly_counts_ee = count_anomalies(df_anamoly, threshold, df_transformed['Anomaly_EE'])

plt.figure(figsize=(10, 6))
plt.bar(df_anamoly.columns, anomaly_counts_ee, color='orange')
plt.title('Count of Anomalies (Elliptic Envelope)')
plt.xlabel('Features')
plt.ylabel('Count of Anomalies')
plt.xticks(rotation=90)
plt.grid(True)
plt.show()
```



In [ ]:
```
# SHAP analysis for Elliptic Envelope
explainer_ee = shap.Explainer(elliptic_envelope.decision_function, df_anamoly)
shap_values_ee = explainer_ee(df_anamoly)

# SHAP summary plot
plt.figure(figsize=(12, 6))
shap.summary_plot(shap_values_ee, df_anamoly, plot_type='bar')
plt.title('SHAP Summary Plot for Elliptic Envelope')
plt.show()
```

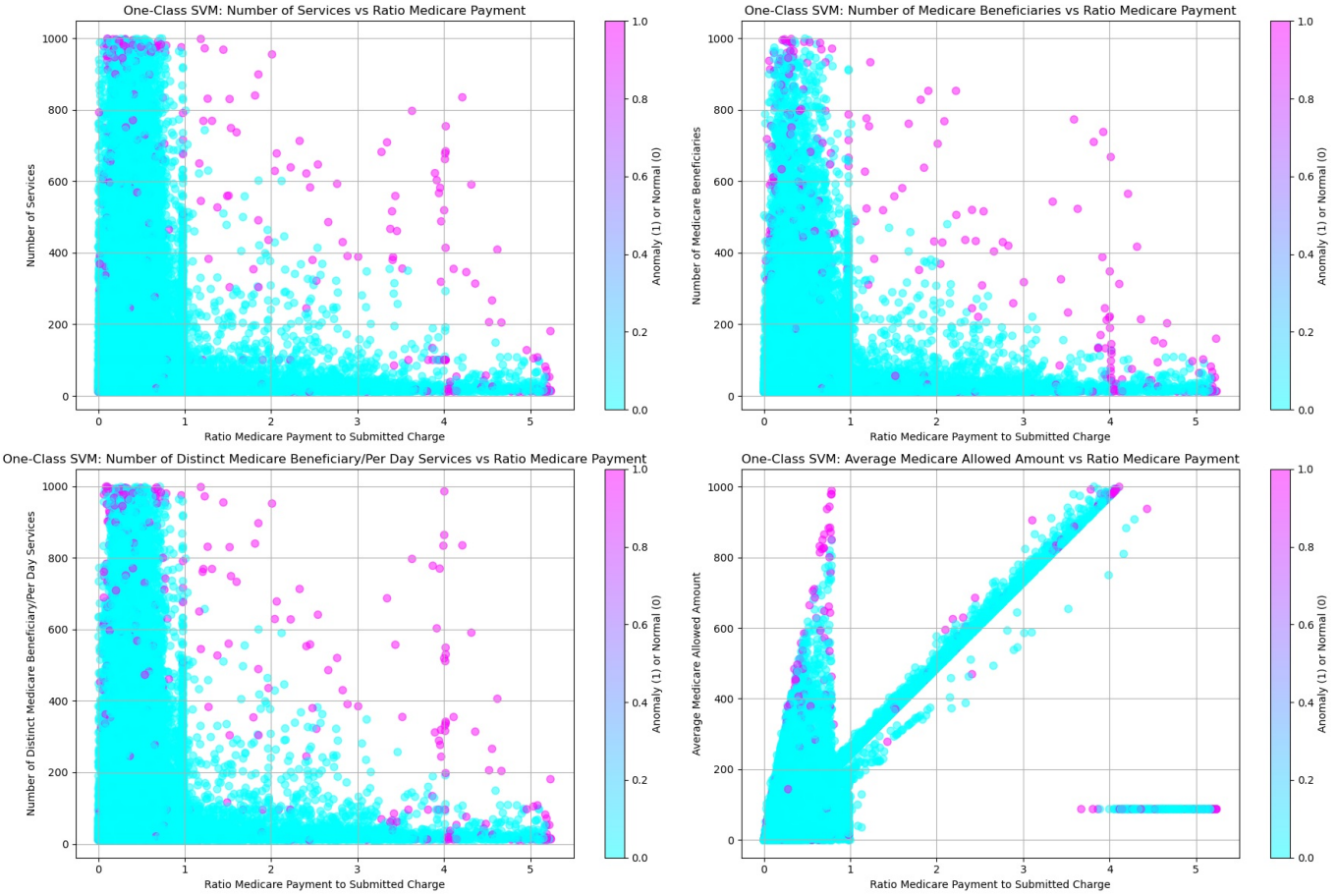
One Class SVM

In [57]:
```
from sklearn.svm import OneClassSVM

# One-Class SVM
one_class_svm = OneClassSVM(nu=0.005)
one_class_svm.fit(df_anamoly)
df_transformed['Anomaly_SVM'] = one_class_svm.predict(df_anamoly)
df_transformed['Anomaly_SVM'] = df_transformed['Anomaly_SVM'].map({1: 0, -1: 1})
print("One-Class SVM anomalies detected:", df_transformed['Anomaly_SVM'].sum())
```

```
One-Class SVM anomalies detected: 504
```

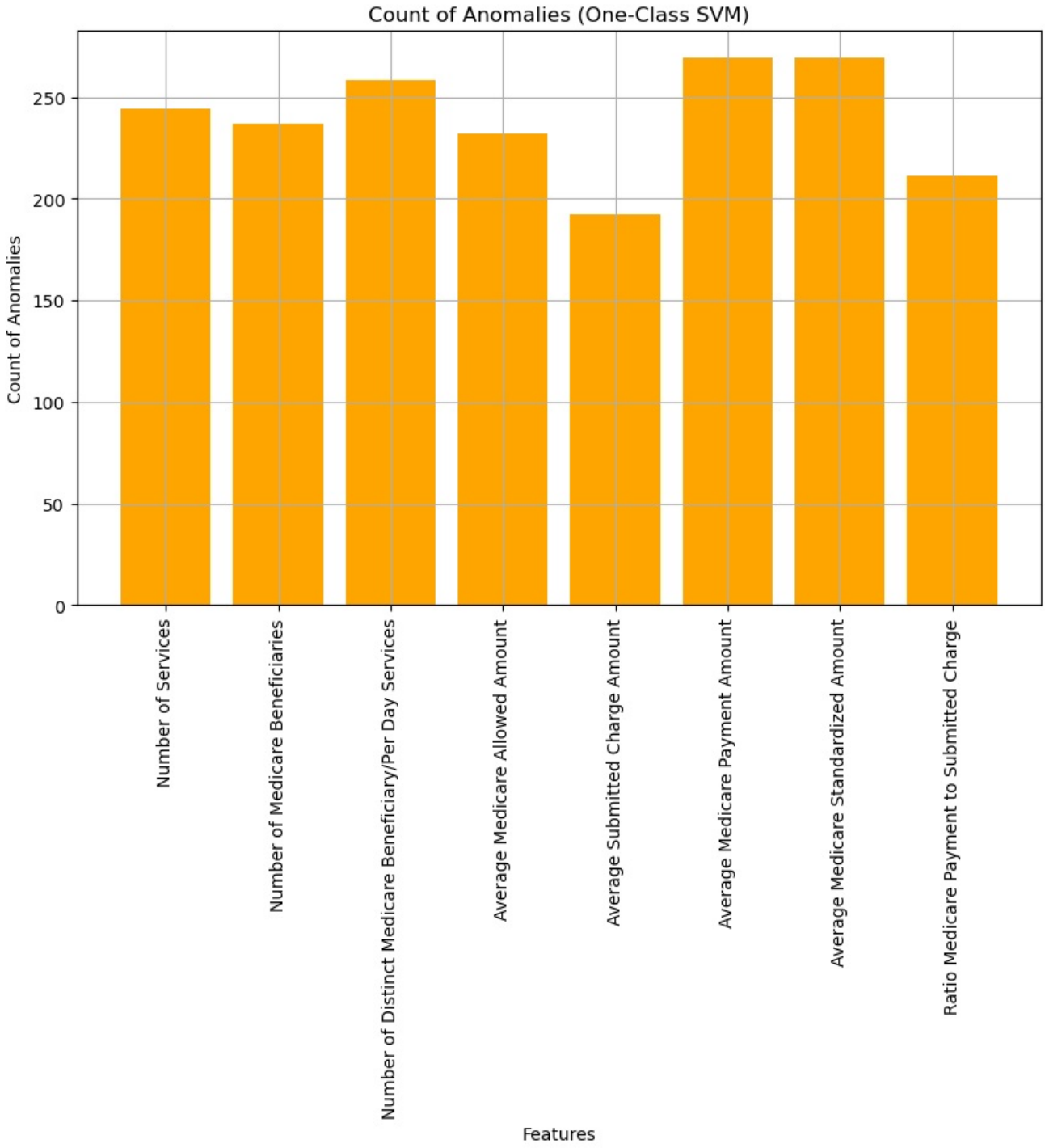
In [58]:
```
# Scatter plots for One-Class SVM
plt.figure(figsize=(18, 12))

for i, feature in enumerate(features):
```

```
    plt.subplot(2, 2, i + 1)
    plt.scatter(df_anamoly['Ratio Medicare Payment to Submitted Charge'], df_anamoly[feature],
                c=df_transformed['Anomaly_SVM'], cmap='cool', s=50, alpha=0.5)
    plt.title(f'One-Class SVM: {feature} vs Ratio Medicare Payment')
    plt.xlabel('Ratio Medicare Payment to Submitted Charge')
    plt.ylabel(feature)
    plt.colorbar(label='Anomaly (1) or Normal (0)')
    plt.grid(True)

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



In [59]:

```
anomaly_counts_svm = count_anomalies(df_anamoly, threshold, df_transformed['Anomaly_SVM'])

plt.figure(figsize=(10, 6))
plt.bar(df_anamoly.columns, anomaly_counts_svm, color='orange')
plt.title('Count of Anomalies (One-Class SVM)')
plt.xlabel('Features')
plt.ylabel('Count of Anomalies')
plt.xticks(rotation=90)
plt.grid(True)
plt.show()
```



In [ ]:
```
# SHAP analysis for One-Class SVM
explainer_svm = shap.Explainer(one_class_svm.decision_function, df_anamoly)
shap_values_svm = explainer_svm(df_anamoly)

# SHAP summary plot
plt.figure(figsize=(12, 6))
shap.summary_plot(shap_values_svm, df_anamoly, plot_type='bar')
plt.title('SHAP Summary Plot for One-Class SVM')
plt.show()
```