Unsupervised Anomaly Detection in Time Series of Bank Transactions

1. Data Cleaning & Exploratory Data Analysis

```
# Data and Stats Packages
import pandas as pd
import numpy as np
import re
import datetime as dt

# Visualization Packages
%matplotlib inline
import matplotlib.pyplot as plt
import seaborn as sns

# Anomaly Detection Packages
from sklearn import preprocessing
from sklearn.ensemble import IsolationForest
from sklearn.svm import OneClassSVM
from sklearn.covariance import EllipticEnvelope
from statsmodels.tsa.seasonal import seasonal_decompose


import warnings
warnings.filterwarnings("ignore")


bank = pd.read_excel('Sample_bank_transaction_data.xlsx')
bank_raw = bank.copy()
```

```
bank.head()
```

	Account No	DATE	TRANSACTION DETAILS	CHQ.NO.	VALUE DATE	WITHDRAWAL AMT	DEPOSIT AMT	B
0	409000611074'	2017-06-29	TRF FROM Indiaforensic SERVICES	NaN	2017-06-29	NaN	1000000.0	10
1	409000611074'	2017-07-05	TRF FROM Indiaforensic SERVICES	NaN	2017-07-05	NaN	1000000.0	20
		2017-	FDRL/INTERNAL		2017-			

```
bank[bank['BALANCE AMT']<0]
```

	Account No	DATE	TRANSACTION DETAILS	CHQ.NO.	VALUE DATE	WITHDRAWAL AMT
2924	409000425051'	2018-10-26	TRF TO Rajendra Kumar	NaN	2018-10-26	1.500000e+07
2926	409000425051'	2018-10-31	TRF TO Myur Joshi	NaN	2018-10-31	3.540000e+08
2927	409000425051'	2018-10-31	TRF TO Indiaforensic SERVICES I	NaN	2018-10-31	9.000000e+05
2928	409000425051'	2018-10-31	409000425051:Int.Coll:01-	NaN	2018-10-31	8.156900e+04
2929	409000425051'	2018-11-27	TRF FROM Indiaforensic SERVICES	NaN	2018-11-27	NaN
...	...	...	...	...	...	...
116196	409000362497'	2019-03-05	TRF TO 1196428 Indiaforensic SE	NaN	2019-03-05	1.179343e+05
116197	409000362497'	2019-03-05	FDRL/INTERNAL FUND TRANSFE	NaN	2019-03-05	NaN

```
bank.shape
```

```
(116201, 9)
```

```
bank.describe()
```

	CHQ.NO.	WITHDRAWAL AMT	DEPOSIT AMT	BALANCE AMT
count	905.000000	5.354900e+04	6.265200e+04	1.162010e+05
mean	791614.503867	4.489190e+06	3.806586e+06	-1.404852e+09
std	151205.932910	1.084850e+07	8.683093e+06	5.348202e+08
min	1.000000	1.000000e-02	1.000000e-02	-2.045201e+09
25%	704231.000000	3.000000e+03	9.900000e+04	-1.690383e+09
50%	873812.000000	4.708300e+04	4.265000e+05	-1.661395e+09
75%	874167.000000	5.000000e+06	4.746411e+06	-1.236888e+09
max	874525.000000	4.594475e+08	5.448000e+08	8.500000e+06

```
bank.columns
```

```
Index(['Account No', 'DATE', 'TRANSACTION DETAILS', 'CHQ.NO.', 'VALUE DATE'
       'WITHDRAWAL AMT', 'DEPOSIT AMT', 'BALANCE AMT', '.'],
      dtype='object')
```

```
bank.rename(columns={'Account No': 'account_no', 'DATE':'date', 'TRANSACTION DE
       'WITHDRAWAL AMT':'withdrawal_amt', 'DEPOSIT AMT':'deposit_amt', 'BALANCE
bank.head(3)
```

	account_no	date	details	chq_no	value_date	withdrawal_amt	dep
0	409000611074'	2017-06-29	TRF FROM Indiaforensic SERVICES	NaN	2017-06-29	NaN	
1	409000611074'	2017-	TRF FROM Indiaforensic	NaN	2017-07-05	NaN	

We have a time series data without anomaly labeling. Let's take a closer look at the features.

```
def first_look(df, col):
    """
    Enables a quick search for characteristics of a column in a data frame.

    df: Data Frame
    col: Column of interest

    """
    val = pd.DataFrame(df[col].value_counts(dropna=False))
    val = val.assign(percent=(df[col].value_counts(dropna=False, normalize=Tru
    info = pd.DataFrame({'Column_Name': [col],'Null_Rows': [df[col].isna().sum
    return info, val
```

i. account_no

```
info , val = first_look(bank, bank.columns[0])
```

```
info
```

	Column_Name	Null_Rows	Column_Type
column_info	account_no	0	object

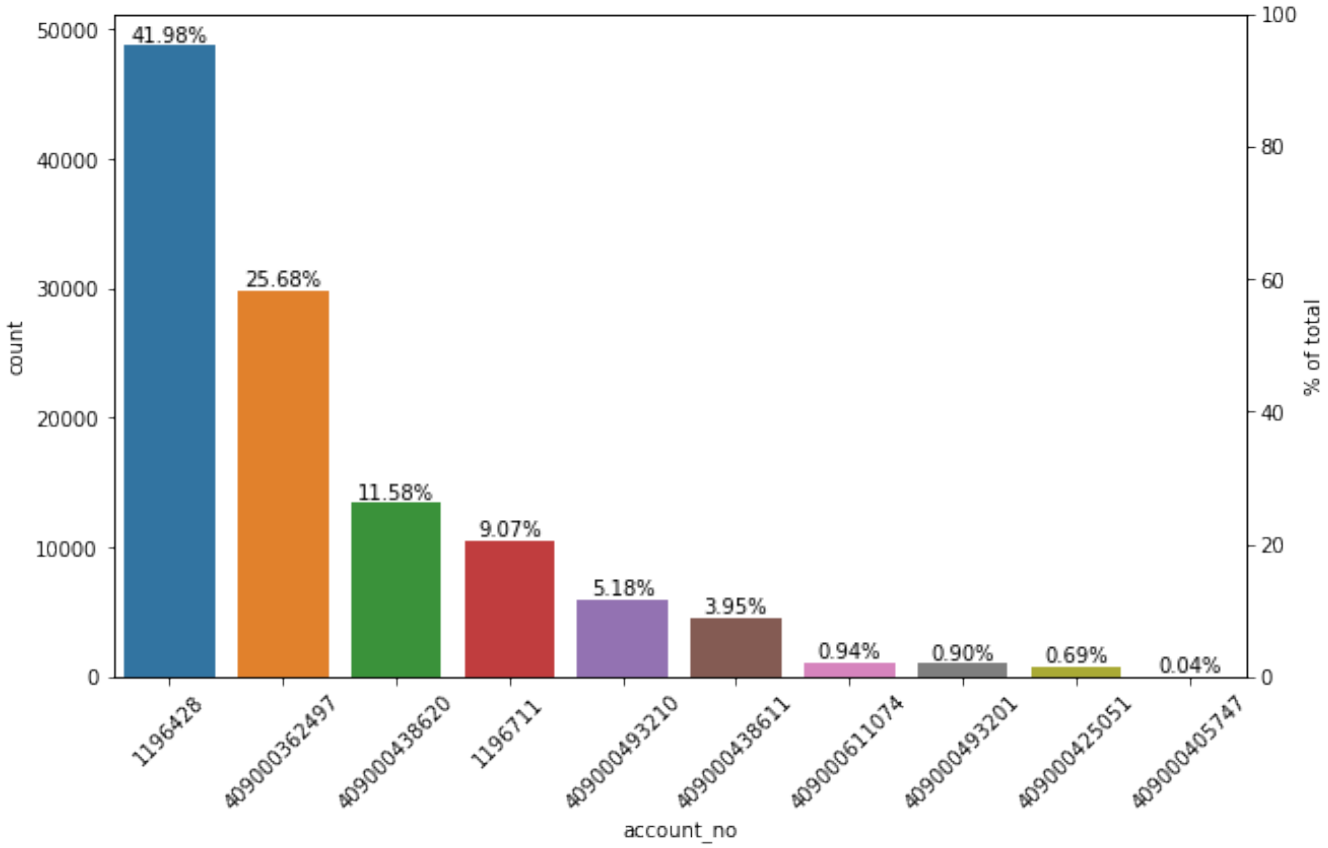
```
val
```

	account_no	percent
1196428'	48779	41.978124
409000362497'	29840	25.679641
409000438620'	13454	11.578214
1196711'	10536	9.067048
409000493210'	6014	5.175515
409000438611'	4588	3.948331
409000611074'	1093	0.940612
409000493201'	1044	0.898443
409000425051'	802	0.690183
409000405747'	51	0.043889

Since **account_no** is a unique indicator of customers (in our case we have 10 customers who have rather unbalanced transaction frequencies), we should keep the data type as string and for future investigation purposes we will remove the ' (last character).

```
bank['account_no'] = bank.account_no.str.extract(r'(\d+)\'')
```

```
plt.figure(figsize=(10,6))
plt.xticks(rotation=45)
fig = sns.countplot(data=bank, x='account_no', order=bank.account_no.value_coun
fig2 = fig.twinx()

fig.yaxis.set_label_position('left')
fig2.yaxis.set_label_position('right')

fig2.set_ylabel('% of total')

for p in fig.patches:
    x=p.get_bbox().get_points()[:,0]
    y=p.get_bbox().get_points()[1,1]
    fig.annotate('{:.2f}%'.format(100.*y/len(bank)), (x.mean(), y),
            ha='center', va='bottom') # set the alignment of the text
fig2.grid(None)
fig2.set_ylim(0,100)
fig2.grid()
plt.show()
```



ii. date

```
info , val = first_look(bank, bank.columns[1])
```

```
info
```

	Column_Name	Null_Rows	Column_Type
column_info	date	0	datetime64[ns]

```
bank.date.apply(lambda x: x.year).value_counts()
```

```
2018    35534
2016    30372
2017    29113
2015    15658
2019     5524
Name: date, dtype: int64
```

```
((bank.date).dt.dayofweek).value_counts()
```

```
0    22662
4    22058
1    21561
3    20446
2    19421
5     9830
6      223
Name: date, dtype: int64
```

```
conditions = [((bank.date).dt.dayofweek  > 4), ((bank.date).dt.dayofweek  < 5)
values = [1, 0]
bank['weekend_date'] = np.select(conditions, values)
```

iii. details

```
info , val = first_look(bank, bank.columns[2])
```

```
info
```

	Column_Name	Null_Rows	Column_Type
column_info	details	2499	object

```
bank[bank.details.isna()].account_no.value_counts()
```

```
409000362497    2484
1196711           15
Name: account_no, dtype: int64
```

```
bank[bank.details.isna()].date.apply(lambda x: x.year).value_counts()
```

```
2015    1259
2016    1240
Name: date, dtype: int64
```

```
bank.details.sample(10)
```

```
28871     NEFT/FDRL334294454/Indiaforensic
98429         RTGS/SBINH16288530565/Indfor
60867           FDRL/INTERNAL FUND TRANSFE
115827          FDRL/INTERNAL FUND TRANSFE
39731                  CASHDEP/NEW-DELHI/
42802                   CASHDEP/SILVASSA/
4959      Indiaforensic MASTER ACQ DOM3001
107510        NEFT/AXIC172569723849/Indfor
35779     NEFT/FDRL392043146/Indiaforensic
36504           FDRL/REAL TIME GROSS SETTL
Name: details, dtype: object
```

This function has the potential to provide information about anomalies. It could help us find new features. For starters, let's define a column that indicates whether a transaction has no proper details value (Null or nonsense values).

```
conditions = [(bank.details.isna())]
values = [1]
bank['details_null_penalty'] = np.select(conditions, values)
```

```
conditions = [(bank.details.str.extract(r'(\w+)')[0].isna())]
values = [1]
bank['details_numbers_penalty'] = np.select(conditions, values)
```

```
bank.details_null_penalty.value_counts()
```

```
0    113702
1      2499
Name: details_null_penalty, dtype: int64
```

```
bank.details_numbers_penalty.value_counts()
```

```
0    112050
1      4151
Name: details_numbers_penalty, dtype: int64
```

This penalty is not a red flag by itself, but can be an additional checkpoint for the anomaly detection results. Let's leave the **details** column at this point and move on to the next feature.

iv. chq_no

```
info , val = first_look(bank, bank.columns[3])
```

```
info
```

	Column_Name	Null_Rows	Column_Type
column_info	chq_no	115296	float64

```
val
```

	chq_no	percent
NaN	115296	99.221177
3.0	3	0.002582
2.0	3	0.002582
4.0	3	0.002582
5.0	3	0.002582
...	...	...
874018.0	1	0.000861
874017.0	1	0.000861
874015.0	1	0.000861
874014.0	1	0.000861
873820.0	1	0.000861

895 rows × 2 columns

```
bank[bank.chq_no<10]
```

	account_no	date	details	chq_no	value_date	wit
2907	409000425051	2017-06-12	Indiaforensic SERVICES INDIA PVT	1.0	2017-06-12	
2908	409000425051	2017-06-12	Indiaforensic SERVICES I P LTD F	2.0	2017-06-12	
2909	409000425051	2017-06-12	Indiaforensic SERVICES I P LTD P	5.0	2017-06-12	
2910	409000425051	2017-06-12	Indiaforensic SERVICES INDIA PVT	6.0	2017-06-12	
2911	409000425051	2017-06-12	Indiaforensic SERVICES I P LTD R	4.0	2017-06-12	
2912	409000425051	2017-06-12	Indiaforensic SERVICES I P LTD R	3.0	2017-06-12	
2913	409000425051	2017-06-14	Indiaforensic SERVICES INDIA PVT	9.0	2017-06-14	
2914	409000425051	2017-06-14	Indiaforensic SERVICES INDIA PVT	7.0	2017-06-14	

		06-14	PVT		
2915	409000425051	2017-06-14	Indiaforensic SERVICES INDIA PVT	8.0	2017-06-14
5654	409000438611	2018-06-25	NEFT/000041992898/Indiaforensic	2.0	2018-06-25
5967	409000438611	2018-08-13	NEFT/000046766266/Indiaforensic	3.0	2018-08-13
6227	409000438611	2018-09-21	NEFT/000050794506/Indiaforensic	4.0	2018-09-21
6229	409000438611	2018-09-21	NEFT/000050794647/Indiaforensic	5.0	2018-09-21
22174	409000438620	2018-06-25	RTGS/YESBH18176501898/Indfor	1.0	2018-06-25
22176	409000438620	2018-06-25	RTGS/YESBH18176502779/Indfor	3.0	2018-06-25
22178	409000438620	2018-06-25	RTGS/YESBH18176503243/Indfor	2.0	2018-06-25
22208	409000438620	2018-06-26	RTGS/YESBH18177599358/Indfor	5.0	2018-06-26
22210	409000438620	2018-06-26	RTGS/YESBH18177600906/Indfor	4.0	2018-06-26
22220	409000438620	2018-06-27	RTGS/YESBH18178695745/Indfor	8.0	2018-06-27
22247	409000438620	2018-06-28	RTGS/YESBH18179801622/Indfor	9.0	2018-06-28

```
bank[~bank.chq_no.isna()].sample(10)
```

	account_no	date	details	chq_no	value_date	wit
31369	1196711	2015-12-09	ROYAL INFOSYS	874020.0	2015-12-09	
36618	1196711	2017-06-06	NEFT/000016693632/Indiaforensic	874421.0	2017-06-06	
77135	1196428	2018-07-06	INTEX TECHNOLOGIES INDIA	704233.0	2018-07-06	
32874	1196711	2016-03-29	RAI ASSOCIATES	874285.0	2016-03-29	
38258	1196428	2015-03-30	RTGS/YESBH15089373218/Indfor	703995.0	2015-03-30	
27739	1196711	2015-08-03	CASHPMT/GURGAON/SELF	873789.0	2015-08-03	
68568	1196428	2017-12-01	NEFT/000026476894/BHARTI	704195.0	2017-12-01	
28086	1196711	2015-08-13	TRESOR SYSTEMS PRIVATE LT	873633.0	2015-08-13	
27726	1196711	2015-08-03	IWSTHCTS1/SUDHARSAN AGINC	873737.0	2015-08-03	
57925	1196428	2016-12-13	CASHPMT/GURGAON/SELF	704175.0	2016-12-13	

```
bank[bank.chq_no<100000].tail()
```

	account_no	date	details	chq_no	value_date	wit
22220	409000438620	2018-06-27	RTGS/YESBH18178695745/Indfor	8.0	2018-06-27	
22245	409000438620	2018-06-28	RTGS/YESBH18179801413/Indfor	10.0	2018-06-28	
22247	409000438620	2018-06-28	RTGS/YESBH18179801622/Indfor	9.0	2018-06-28	
37589	1196428	2015-01-02	RTGS/YESBH15002745737/Indfor	4549.0	2015-01-02	
37593	1196428	2015-01-03	FUND TRF TO Indiaforensic SERVI	4550.0	2015-01-03	

```
bank['cheque_penalty'] = np.where(bank.chq_no<11, 1, 0)
```

```
bank.cheque_penalty.value_counts()
```

```
0    116180
1        21
Name: cheque_penalty, dtype: int64
```

Again, this penalty is not a red flag in itself, but on the other hand, given the incorrect check numbers, it can be an additional check point for the anomaly detection results. Let's leave the **chq_no** column at this point and move on to the next feature.

v. value_date

```
info , val = first_look(bank, bank.columns[4])
```

```
info
```

	Column_Name	Null_Rows	Column_Type
column_info	value_date	0	datetime64[ns]

```
bank['day_diff'] = ((bank.date - bank.value_date) / np.timedelta64(1,'D')).asty
```

```
bank.day_diff.value_counts()
```

```
 0     116066
 1         86
 3         15
 2         11
 5          9
 4          8
 29         2
-1          1
 18         1
 8          1
 6          1
Name: day_diff, dtype: int64
```

```
bank[(bank.day_diff < 0) | (bank.day_diff > 5)]
```

	account_no	date	details	chq_no	value_date	withdrawal_a
63340	1196428	2017-05-16	FT ZL1705177BD415D1 SHREE	NaN	2017-05-17	N
63717	1196428	2017-06-06	Payments For : 9090000405	NaN	2017-05-31	657534
103332	409000362497	2017-04-05	REPAYMENT CREDIT [7090021	NaN	2017-03-07	N
103335	409000362497	2017-04-05	Sweep Trf To: 40900036427	NaN	2017-03-07	7952045
104111	409000362497	2017-05-05	FD BOOKING 365 DAYS DEPO	NaN	2017-04-27	58500000
112081	409000362497	2018-04-27	Sweep Trf To: 40900036427	NaN	2018-04-09	9176351

As one could obviously see, we have obtained an important feature that we will look at more closely in the anomaly analysis. Let's have a quick look whether we have weekend value_dates.

```
((bank.value_date).dt.dayofweek  > 4).value_counts()
```

```
False    106146
True      10055
Name: value_date, dtype: int64
```

```
conditions = [((bank.value_date).dt.dayofweek  > 4), ((bank.value_date).dt.day
values = [1, 0]
bank['weekend_value_date'] = np.select(conditions, values)
```

vi. withdrawal_amt

```
info , val = first_look(bank, bank.columns[5])
```

```
info
```

	Column_Name	Null_Rows	Column_Type
column_info	withdrawal_amt	62652	float64

```
bank.withdrawal_amt.describe()
```

```
count    5.354900e+04
mean     4.489190e+06
std      1.084850e+07
min      1.000000e-02
25%      3.000000e+03
50%      4.708300e+04
75%      5.000000e+06
max      4.594475e+08
Name: withdrawal_amt, dtype: float64
```

```
bank[~bank.withdrawal_amt.isna()].count()
```

```
account_no                53549
date                      53549
details                   53549
chq_no                      905
value_date                53549
withdrawal_amt            53549
deposit_amt                   0
balance_amt               53549
.                         53549
weekend_date              53549
details_null_penalty      53549
details_numbers_penalty   53549
cheque_penalty            53549
day_diff                  53549
weekend_value_date        53549
dtype: int64
```

```
bank[bank.withdrawal_amt.isna()].count()
```

```
account_no                62652
date                      62652
details                   60153
chq_no                        0
value_date                62652
withdrawal_amt                0
deposit_amt               62652
balance_amt               62652
.                         62652
weekend_date              62652
details_null_penalty      62652
details_numbers_penalty   62652
cheque_penalty            62652
day_diff                  62652
weekend_value_date        62652
dtype: int64
```

```
pd.DataFrame(bank.groupby('account_no').withdrawal_amt.count()).sort_values('w
```

account_no	withdrawal_amt
1196428	16687
409000362497	15477
409000438620	8391
409000493210	5227
1196711	5025
409000438611	1333
409000611074	778
409000493201	575
409000405747	28
409000425051	28

```
conditions = [((bank.balance_amt+bank.withdrawal_amt)==0), ((bank.balance_amt+
values = [0, 100*(bank.withdrawal_amt/(bank.balance_amt+bank.withdrawal_amt))]
bank['withdrawal_over_balance'] = np.select(conditions, values)
```

```
bank['withdrawal_amt'] = bank.withdrawal_amt.fillna(0)
```

```
bank['withdrawal_over_balance'] = bank.withdrawal_over_balance.fillna(0)
```

```
bank[bank.withdrawal_amt!=0].head()
```

	account_no	date	details	chq_no	value_date	withdrawal_amt	deposi
10	409000611074	2017-08-16	INDO GIBL Indiaforensic STL01071	NaN	2017-08-16	133900.0	
11	409000611074	2017-08-16	INDO GIBL Indiaforensic STL02071	NaN	2017-08-16	18000.0	
12	409000611074	2017-08-16	INDO GIBL Indiaforensic STL03071	NaN	2017-08-16	5000.0	
13	409000611074	2017-08-16	INDO GIBL Indiaforensic STL04071	NaN	2017-08-16	195800.0	
14	409000611074	2017-08-16	INDO GIBL Indiaforensic STL05071	NaN	2017-08-16	81600.0	

vii. deposit_amt

```
info , val = first_look(bank, bank.columns[6])
```

```
info
```

	Column_Name	Null_Rows	Column_Type
column_info	deposit_amt	53549	float64

```
bank.deposit_amt.describe()
```

```
count    6.265200e+04
mean     3.806586e+06
std      8.683093e+06
min      1.000000e-02
25%      9.900000e+04
50%      4.265000e+05
75%      4.746411e+06
max      5.448000e+08
Name: deposit_amt, dtype: float64
```

```
bank[~bank.deposit_amt.isna()].count()
```

```
account_no                62652
date                      62652
details                   60153
chq_no                        0
value_date                62652
withdrawal_amt            62652
deposit_amt               62652
balance_amt               62652
.                         62652
weekend_date              62652
details_null_penalty      62652
details_numbers_penalty   62652
cheque_penalty            62652
day_diff                  62652
weekend_value_date        62652
withdrawal_over_balance   62652
dtype: int64
```

```
bank[bank.deposit_amt.isna()].count()
```

```
account_no                53549
date                      53549
details                   53549
chq_no                      905
value_date                53549
withdrawal_amt            53549
deposit_amt                   0
balance_amt               53549
.                         53549
weekend_date              53549
details_null_penalty      53549
details_numbers_penalty   53549
cheque_penalty            53549
day_diff                  53549
weekend_value_date        53549
withdrawal_over_balance   53549
dtype: int64
```

```
pd.DataFrame(bank.groupby('account_no').deposit_amt.count()).sort_values('depo
```

account_no	deposit_amt
1196428	32092
409000362497	14363
1196711	5511
409000438620	5063
409000438611	3255
409000493210	787
409000425051	774
409000493201	469
409000611074	315
409000405747	23

```
bank[bank.deposit_amt.isna() & bank.withdrawal_amt.isna()].count()
```

```
account_no                0
date                      0
details                   0
chq_no                    0
value_date                0
withdrawal_amt            0
deposit_amt               0
balance_amt               0
.                         0
weekend_date              0
details_null_penalty      0
details_numbers_penalty   0
cheque_penalty            0
day_diff                  0
weekend_value_date        0
withdrawal_over_balance   0
dtype: int64
```

```
conditions = [((bank.balance_amt-bank.deposit_amt)==0), ((bank.balance_amt-ban
values = [0, 100*(bank.deposit_amt/(bank.balance_amt-bank.deposit_amt))]
bank['deposit_over_balance'] = np.select(conditions, values)
bank['deposit_over_balance'] = bank.deposit_over_balance.fillna(0)
```

```
bank['deposit_amt'] = bank.deposit_amt.fillna(0)
```

viii. balance_amt

```
from google.colab import drive
drive.mount('/content/drive')
```

```
Mounted at /content/drive
```

```
info , val = first_look(bank, bank.columns[7])
```

```
info
```

	Column_Name	Null_Rows	Column_Type
column_info	balance_amt	0	float64

```
bank.balance_amt.describe()
```

```
count    1.162010e+05
mean    -1.404852e+09
std      5.348202e+08
min     -2.045201e+09
25%     -1.690383e+09
50%     -1.661395e+09
75%     -1.236888e+09
max      8.500000e+06
Name: balance_amt, dtype: float64
```

```
bank[bank.balance_amt.isna()].count()
```

```
account_no                0
date                      0
details                   0
chq_no                    0
value_date                0
withdrawal_amt            0
deposit_amt               0
balance_amt               0
.                         0
weekend_date              0
details_null_penalty      0
details_numbers_penalty   0
cheque_penalty            0
day_diff                  0
weekend_value_date        0
withdrawal_over_balance   0
deposit_over_balance      0
dtype: int64
```

ix. Dropping Empty Column

```
info , val = first_look(bank, bank.columns[8])
```

```
info
```

	Column_Name	Null_Rows	Column_Type
column_info	.	0	object

```
val
```

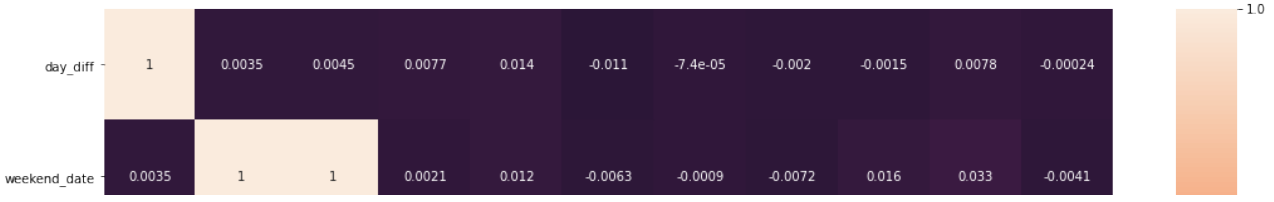
	.	percent
.	116201	100.0

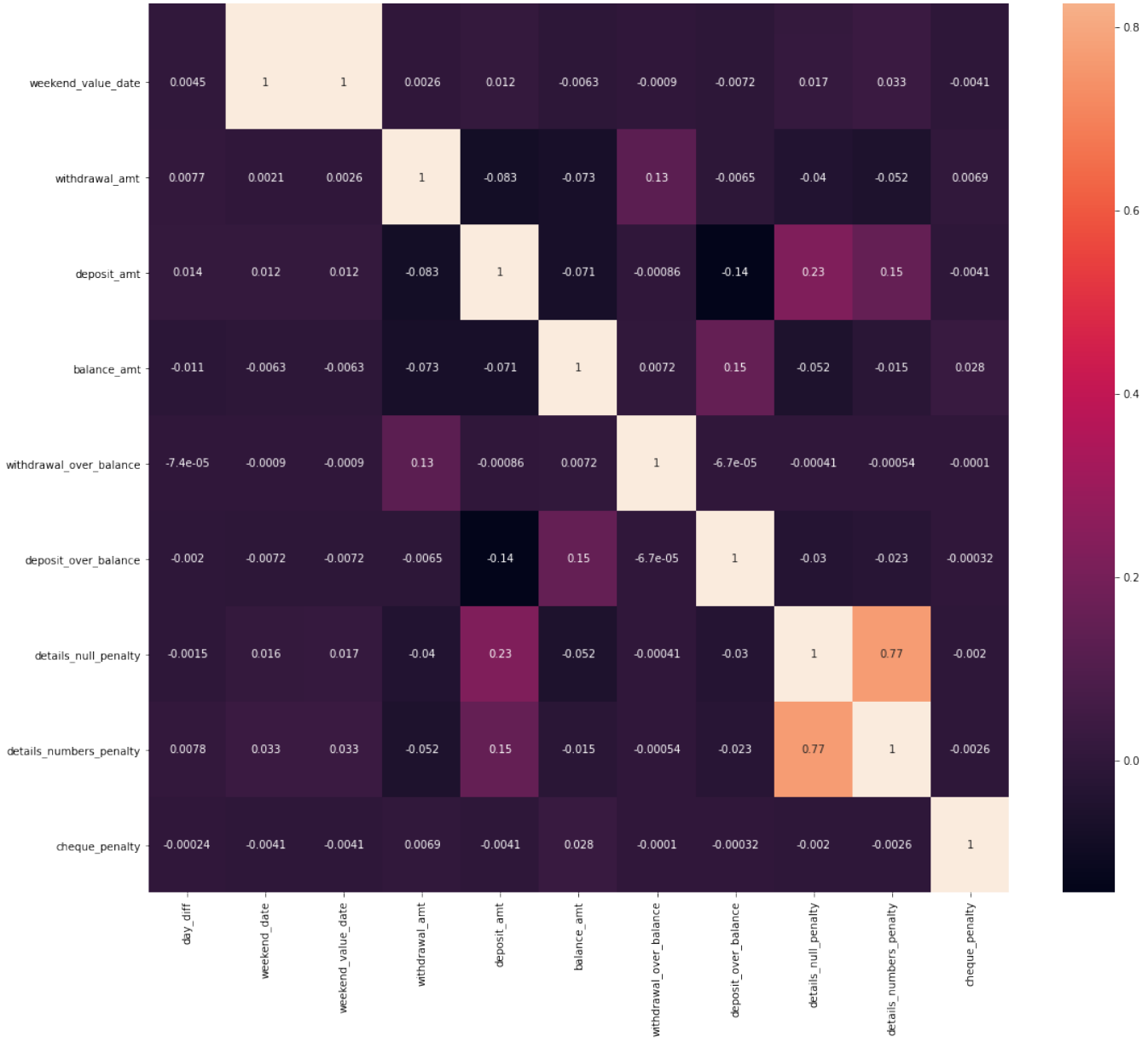
```
bank.drop(columns=['.'], inplace=True, axis=1)

bank_detailed = bank.copy()

bank = bank[['account_no', 'date', 'value_date', 'day_diff', 'weekend_date', '

bank.head()
```

	account_no	date	value_date	day_diff	weekend_date	weekend_value_date
0	409000611074	2017-06-29	2017-06-29	0	0	0
1	409000611074	2017-07-05	2017-07-05	0	0	0
2	409000611074	2017-07-18	2017-07-18	0	0	0
3	409000611074	2017-08-01	2017-08-01	0	0	0
4	409000611074	2017-08-16	2017-08-16	0	0	0

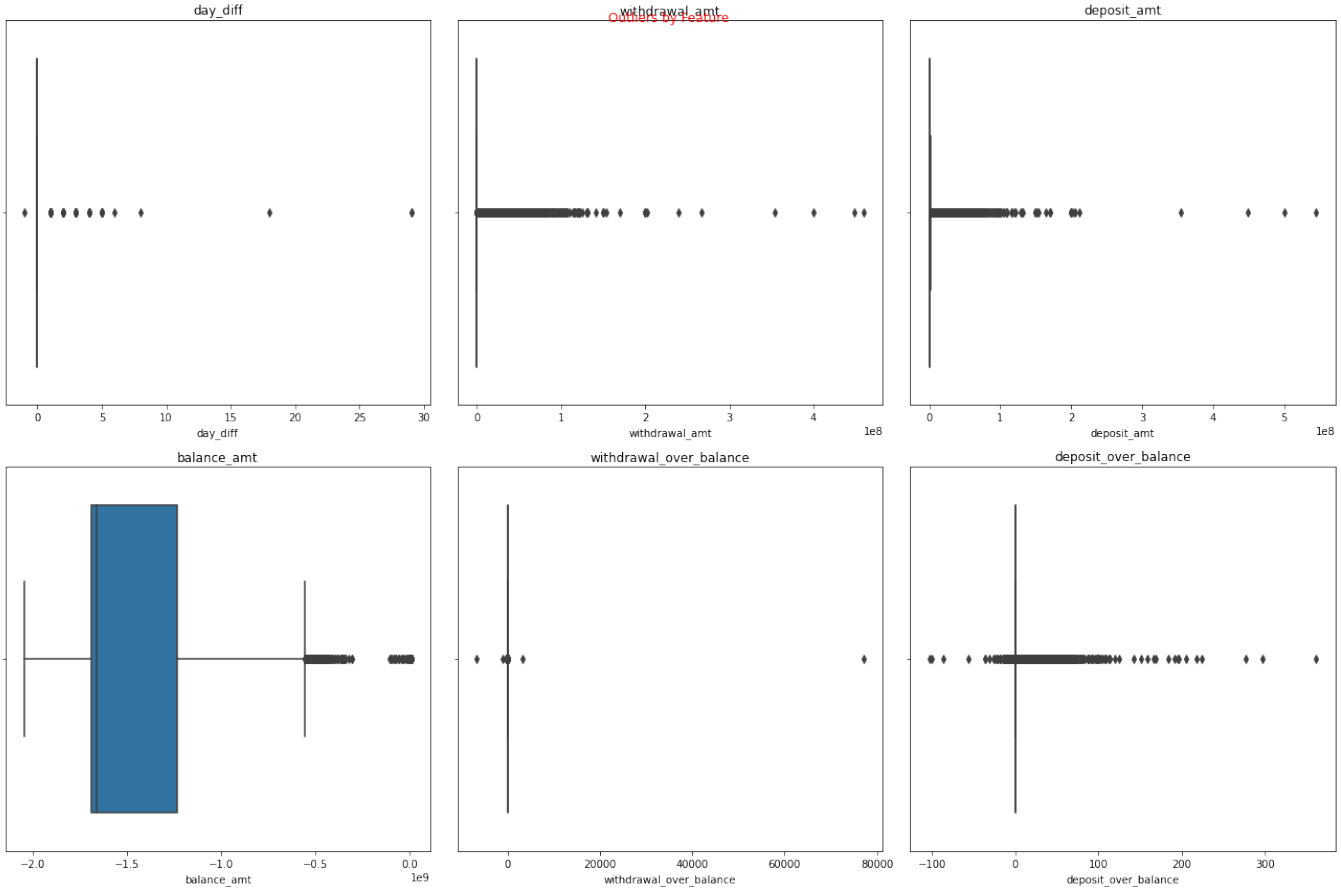
2. Data Visualization

```
plt.figure(figsize=(18, 18))
sns.heatmap(bank.corr(), annot=True)
plt.yticks(rotation=0)
plt.show()
```



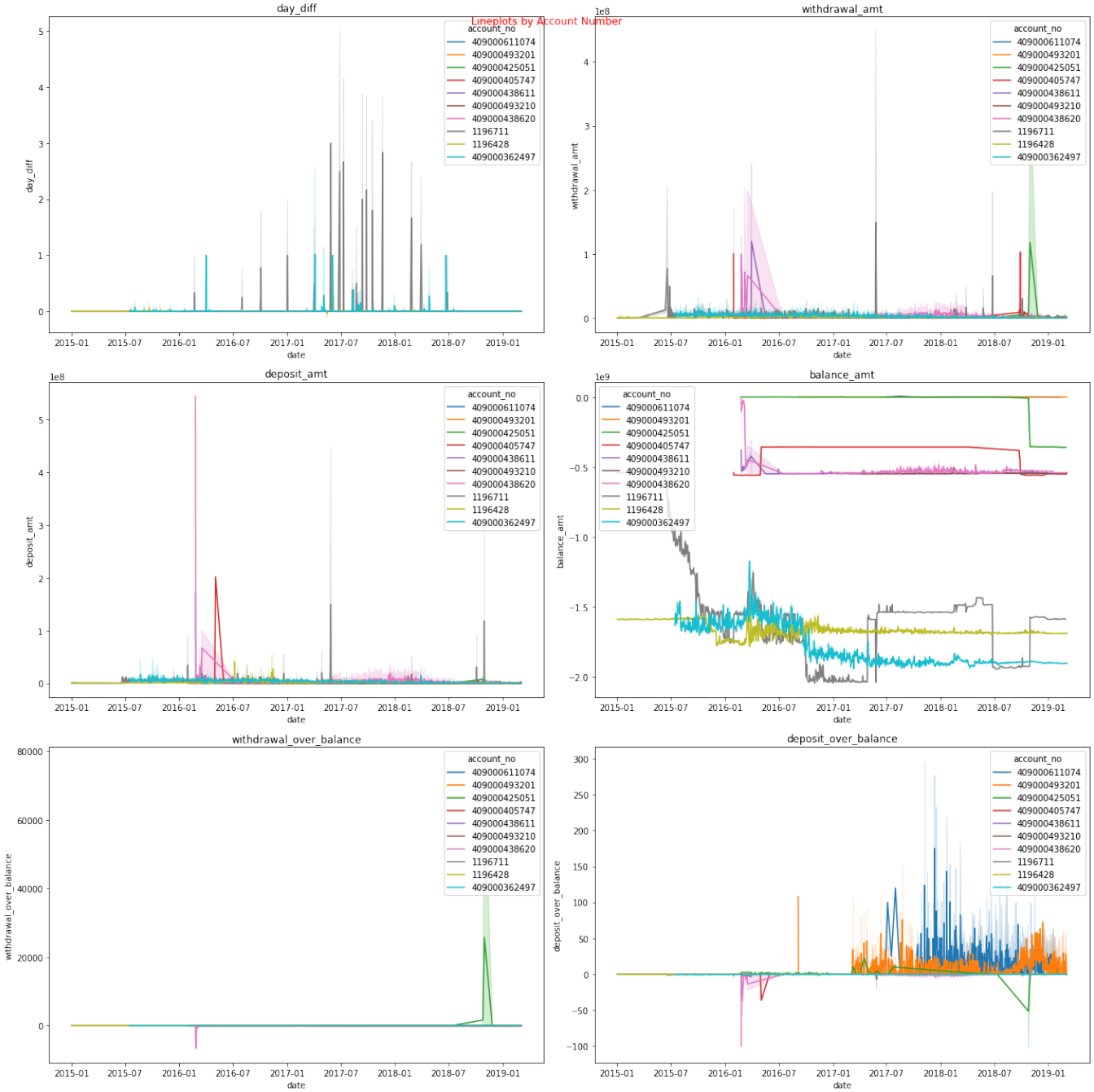

weekend_value_date 0.0045 1 1 0.0026 0.012 -0.0063 -0.0009 -0.0072 0.017 0.033 -0.0041
withdrawal_amt 0.0077 0.0021 0.0026 1 -0.083 -0.073 0.13 -0.0065 -0.04 -0.052 0.0069
deposit_amt 0.014 0.012 0.012 -0.083 1 -0.071 -0.00086 -0.14 0.23 0.15 -0.0041
balance_amt -0.011 -0.0063 -0.0063 -0.073 -0.071 1 0.0072 0.15 -0.052 -0.015 0.028
withdrawal_over_balance -7.4e-05 -0.0009 -0.0009 0.13 -0.00086 0.0072 1 -6.7e-05 -0.00041 -0.00054 -0.0001
deposit_over_balance -0.002 -0.0072 -0.0072 -0.0065 -0.14 0.15 -6.7e-05 1 -0.03 -0.023 -0.00032
details_null_penalty -0.0015 0.016 0.017 -0.04 0.23 -0.052 -0.00041 -0.03 1 0.77 -0.002
details_numbers_penalty 0.0078 0.033 0.033 -0.052 0.15 -0.015 -0.00054 -0.023 0.77 1 -0.0026
cheque_penalty -0.00024 -0.0041 -0.0041 0.0069 -0.0041 0.028 -0.0001 -0.00032 -0.002 -0.0026 1
day_diff
weekend_date
weekend_value_date
withdrawal_amt
deposit_amt
balance_amt
withdrawal_over_balance
deposit_over_balance
details_null_penalty
details_numbers_penalty
cheque_penalty
0.8
0.6
0.4
0.2
0.0

```
features = ['day_diff', 'withdrawal_amt', 'deposit_amt', 'balance_amt', 'withd


fig, axes = plt.subplots(2,3, sharex=False, figsize=(18, 12))
fig.suptitle('Outliers by Feature', color='r' )

for i in range(2):
    for j in range(3):
        sns.boxplot(ax=axes[i,j], x= features[3*i + j], data = bank)
        axes[i,j].set_title(f'{features[3*i + j]}')

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




```
features = ['day_diff', 'withdrawal_amt', 'deposit_amt', 'balance_amt', 'withd
```

```
fig, axes = plt.subplots(3,2, sharex=False, figsize=(18, 18))
fig.suptitle('Lineplots by Account Number', color='r' )

for i in range(3):
    for j in range(2):
        sns.lineplot(ax=axes[i,j], y= features[2*i + j], x = 'date', data = ba
        axes[i,j].set_title(f'{features[2*i + j]}')

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



3. Anomaly Detection Whole Dataset (Account No. as a Feature)

Before getting started with the anomaly detection we need to convert categorical variable into dummy/indicator variables.

```
bank_premodel = bank.copy()
```

```
bank = pd.get_dummies(bank, columns = ['account_no'])
```

```
bank.columns
```

```
Index(['date', 'value_date', 'day_diff', 'weekend_date', 'weekend_value_dat
       'withdrawal_amt', 'deposit_amt', 'balance_amt',
       'withdrawal_over_balance', 'deposit_over_balance',
       'details_null_penalty', 'details_numbers_penalty', 'cheque_penalty',
       'account_no_1196428', 'account_no_1196711', 'account_no_409000362497
       'account_no_409000405747', 'account_no_409000425051',
       'account_no_409000438611', 'account_no_409000438620',
       'account_no_409000493201', 'account_no_409000493210',
       'account_no_409000611074'],
      dtype='object')
```

```
bank.head(3)
```

	date	value_date	day_diff	weekend_date	weekend_value_date	withdrawal_
0	2017-06-29	2017-06-29	0	0	0	
1	2017-07-05	2017-07-05	0	0	0	
2	2017-07-18	2017-07-18	0	0	0	

```
(bank.weekend_date + bank.weekend_value_date).value_counts()
```

```
0    106140
2     10047
1        14
dtype: int64
```

i. Isolation Forest Anomaly Detection

- Isolation Forest returns the anomaly score of each sample using the IsolationForest algorithm.
- The IsolationForest 'isolates' observations by randomly selecting a feature and then randomly selecting a split value between the maximum and minimum values of the selected feature.
- Since recursive partitioning can be represented by a tree structure, the number of splittings required to isolate a sample is equivalent to the path length from the root node to the terminating node.
- This path length, averaged over a forest of such random trees, is a measure of normality and our decision function.
- Random partitioning produces noticeably shorter paths for anomalies. Hence, when a forest of random trees collectively produce shorter path lengths for particular samples, they are highly likely to be anomalies.

link : https://scikit-learn.org/stable/modules/generated/sklearn.ensemble.IsolationForest.html

```
from sklearn.preprocessing import StandardScaler
bank_iso = bank.drop(columns=['date', 'value_date'], axis=1)
scaler = StandardScaler()
bank_iso_scaled = pd.DataFrame(scaler.fit_transform(bank_iso), columns=bank_iso
```

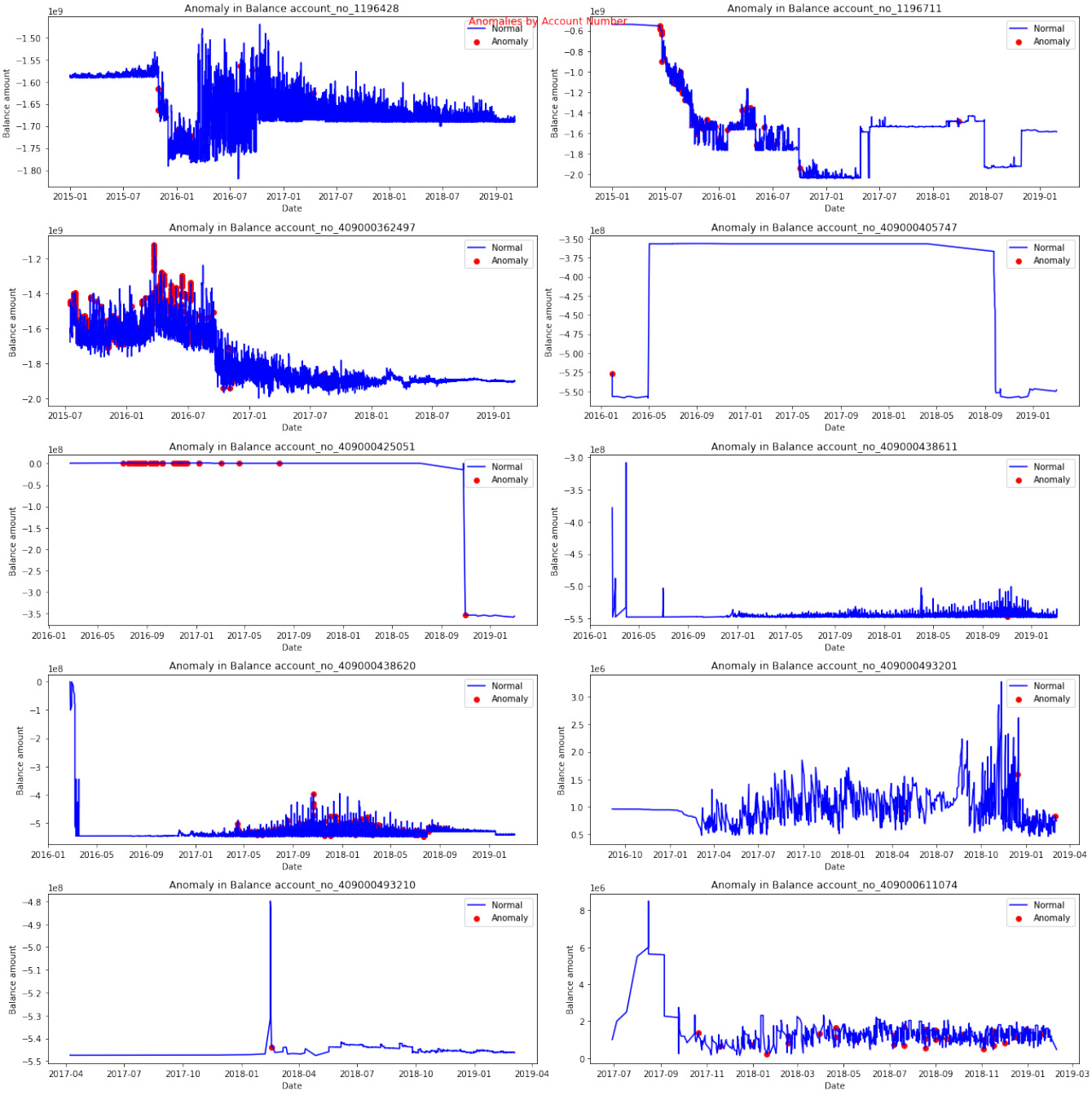
```
bank_main = bank.copy()
outliers_fraction = .007
model = IsolationForest(contamination=outliers_fraction)
model.fit(bank_iso_scaled)
bank_main['anomaly_isolation_forest'] = pd.Series(model.predict(bank_iso_scale
```

```
bank_main['anomaly_isolation_forest'].value_counts()
```

```
0    115396
1       805
Name: anomaly_isolation_forest, dtype: int64
```

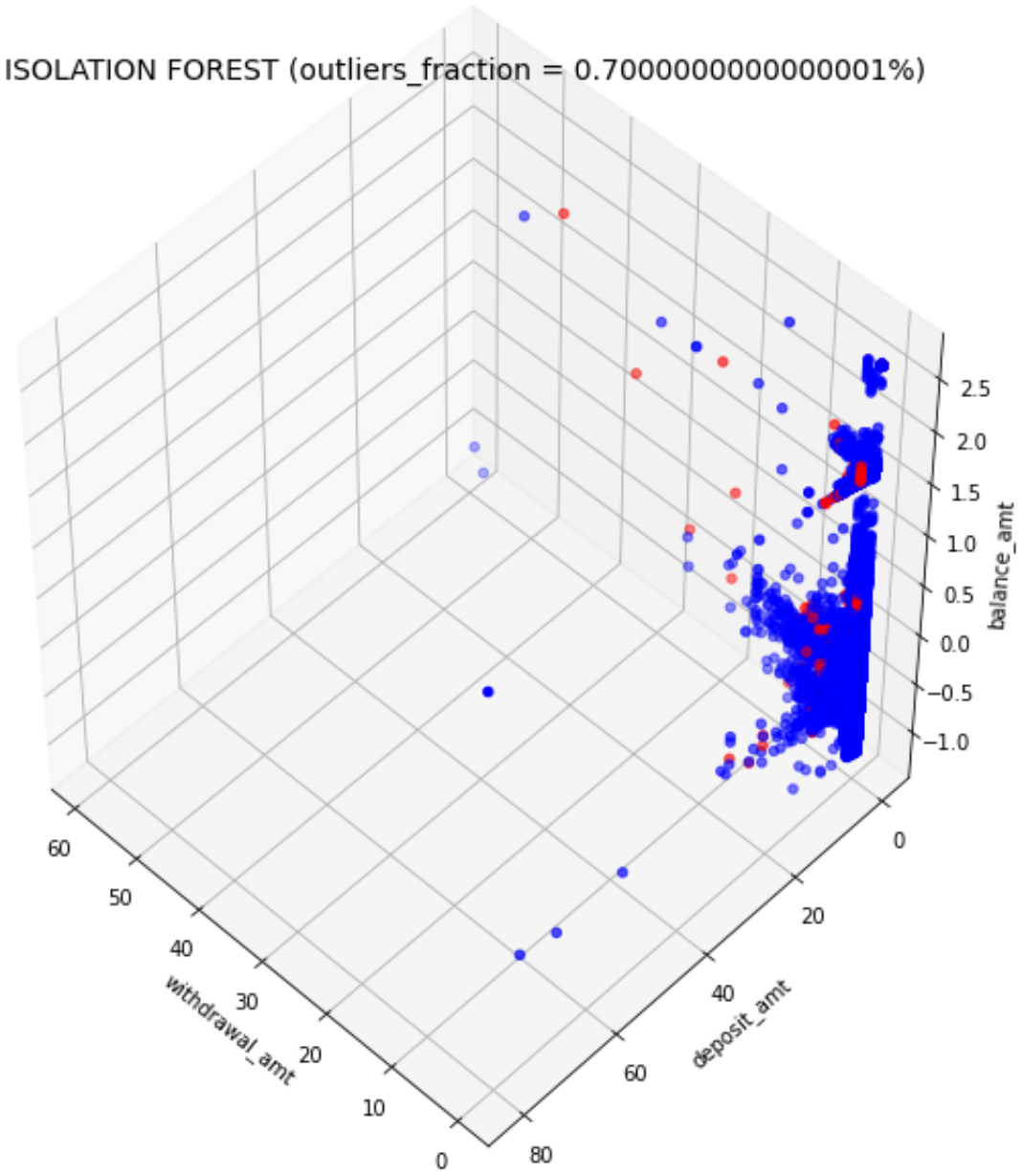
```
features = ['account_no_1196428', 'account_no_1196711', 'account_no_4090003624
            'account_no_409000438611', 'account_no_409000438620', 'account_no_
fig, axes = plt.subplots(5,2, sharex=False, figsize=(18, 18))
fig.suptitle('Anomalies by Account Number', color='r' )
```

```
for i in range(5):
    for j in range(2):

        df = bank_main[bank_main[features[2*i + j]]==1]
        a= df.loc[df['anomaly_isolation_forest']==1, ['date', 'balance_amt']]

        axes[i,j].plot(df['date'], df['balance_amt'], color='blue', label='Nor
        axes[i,j].scatter(a['date'], a['balance_amt'], color='red', label='Ano
        axes[i,j].set_title(f'Anomaly in Balance {features[2*i + j]}')
        axes[i,j].set_xlabel('Date')
        axes[i,j].set_ylabel('Balance amount')
        axes[i,j].legend()

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



```
from mpl_toolkits.mplot3d import Axes3D
labels = bank_main.anomaly_isolation_forest
colors = {0:'blue', 1:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(bank_iso_scaled.iloc[:,3], bank_iso_scaled.iloc[:,4], bank_iso_scal
ax.set_title(f'ISOLATION FOREST (outliers_fraction = {100*outliers_fraction}%)
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



ii. OneClassSVM Anomaly Detection

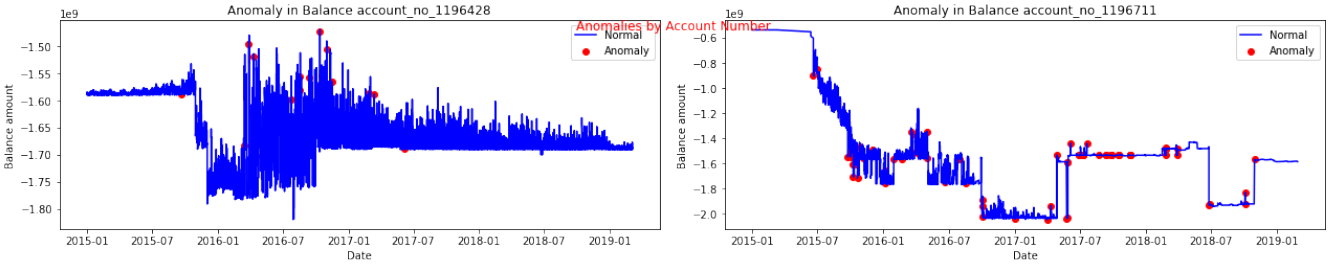
```
bank_svm = bank.drop(columns=['date', 'value_date'], axis=1)
scaler = StandardScaler()
bank_svm_scaled = pd.DataFrame(scaler.fit_transform(bank_svm), columns=bank_svm
```

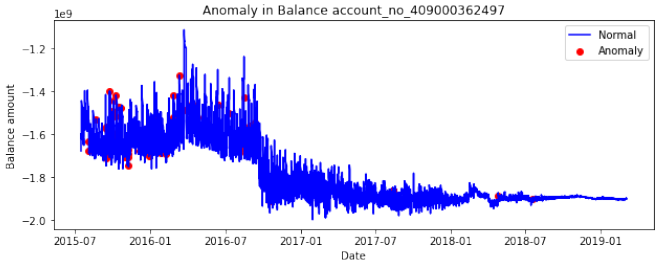
```
outliers_fraction = .005
model = OneClassSVM(nu=outliers_fraction, kernel='rbf', gamma=.01)
model.fit(bank_svm_scaled)
bank_main['anomaly_one_class_svm'] = pd.Series(model.predict(bank_svm_scaled))
```

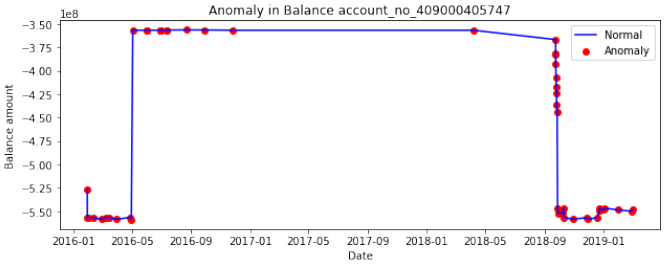
```
bank_main['anomaly_one_class_svm'].value_counts()
```

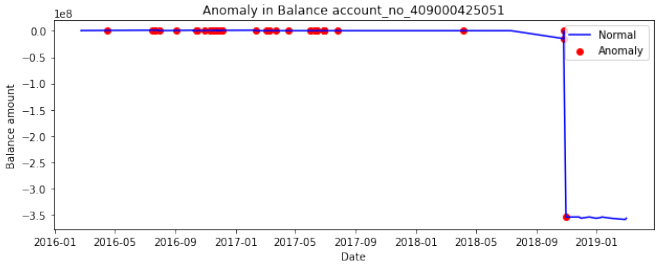
```
   0    115589
   1       612
   Name: anomaly_one_class_svm, dtype: int64
```

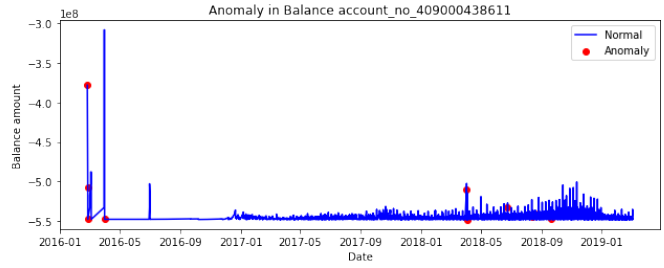
```
features = ['account_no_1196428', 'account_no_1196711', 'account_no_4090003624
            'account_no_409000438611', 'account_no_409000438620', 'account_no_
fig, axes = plt.subplots(5,2, sharex=False, figsize=(18, 18))
fig.suptitle('Anomalies by Account Number', color='r' )

for i in range(5):
    for j in range(2):

        df = bank_main[bank_main[features[2*i + j]]==1]
        a= df.loc[df['anomaly_one_class_svm']==1, ['date', 'balance_amt']]

        axes[i,j].plot(df['date'], df['balance_amt'], color='blue', label='Nor
        axes[i,j].scatter(a['date'], a['balance_amt'], color='red', label='Ano
        axes[i,j].set_title(f'Anomaly in Balance {features[2*i + j]}')
        axes[i,j].set_xlabel('Date')
        axes[i,j].set_ylabel('Balance amount')
        axes[i,j].legend()

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

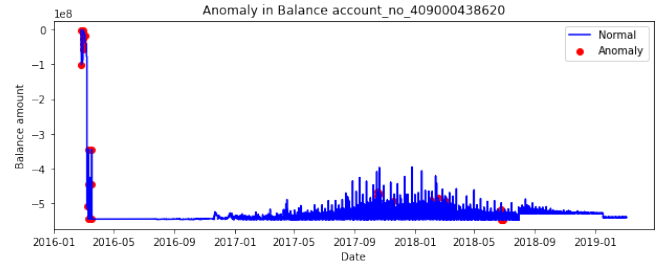


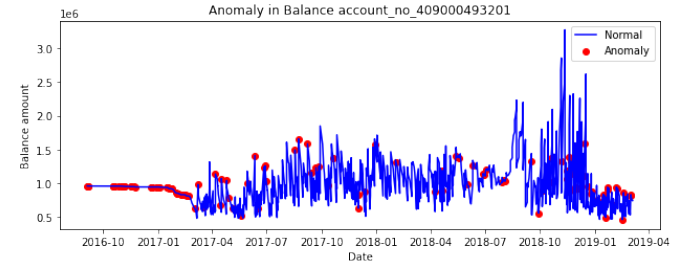

Anomaly in Balance account_no_409000362497
1e9
Normal
Anomaly
Balance amount
Date

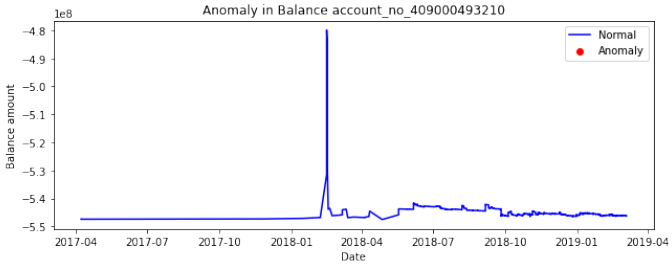

Anomaly in Balance account_no_409000405747
1e8
Normal
Anomaly
Balance amount
Date

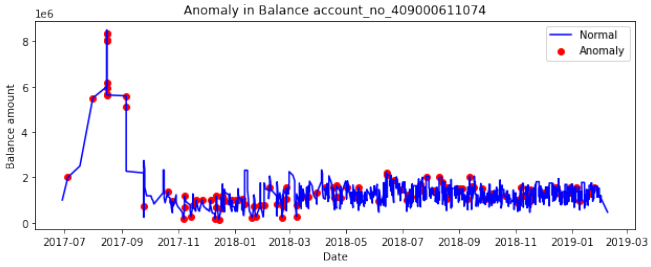

Anomaly in Balance account_no_409000425051
1e8
Normal
Anomaly
Balance amount
Date


Anomaly in Balance account_no_409000438611
1e8
Normal
Anomaly
Balance amount
Date


Anomaly in Balance account_no_409000438620
1e8
Normal
Anomaly
Balance amount
Date

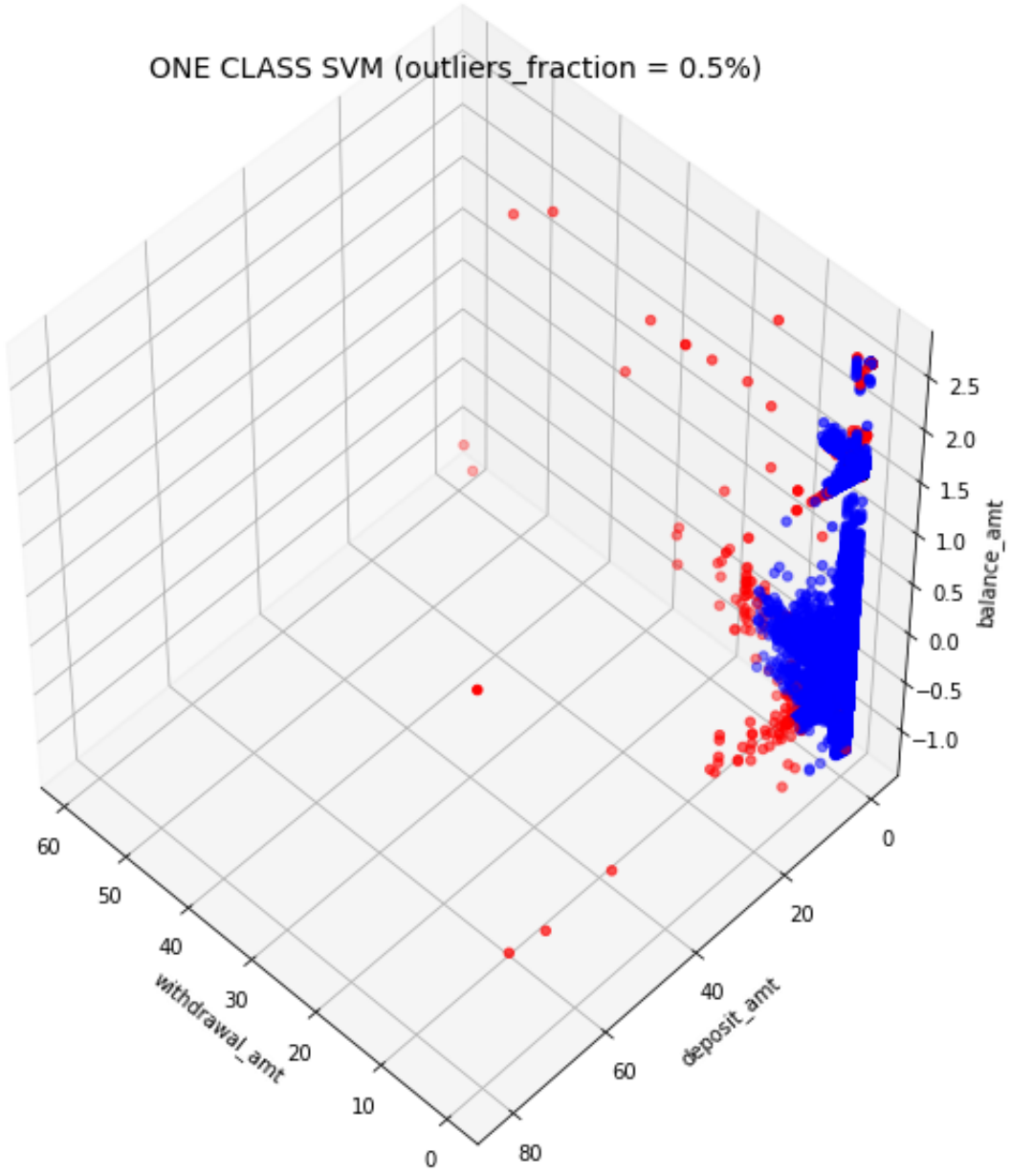

Anomaly in Balance account_no_409000493201
1e6
Normal
Anomaly
Balance amount
Date


Anomaly in Balance account_no_409000493210
1e8
Normal
Anomaly
Balance amount
Date


Anomaly in Balance account_no_409000611074
1e6
Normal
Anomaly
Balance amount
Date

```
labels = bank_main.anomaly_one_class_svm
colors = {0:'blue', 1:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(bank_svm_scaled.iloc[:,3], bank_svm_scaled.iloc[:,4], bank_svm_scal
ax.set_title(f'ONE CLASS SVM (outliers_fraction = {100*outliers_fraction}%)',
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



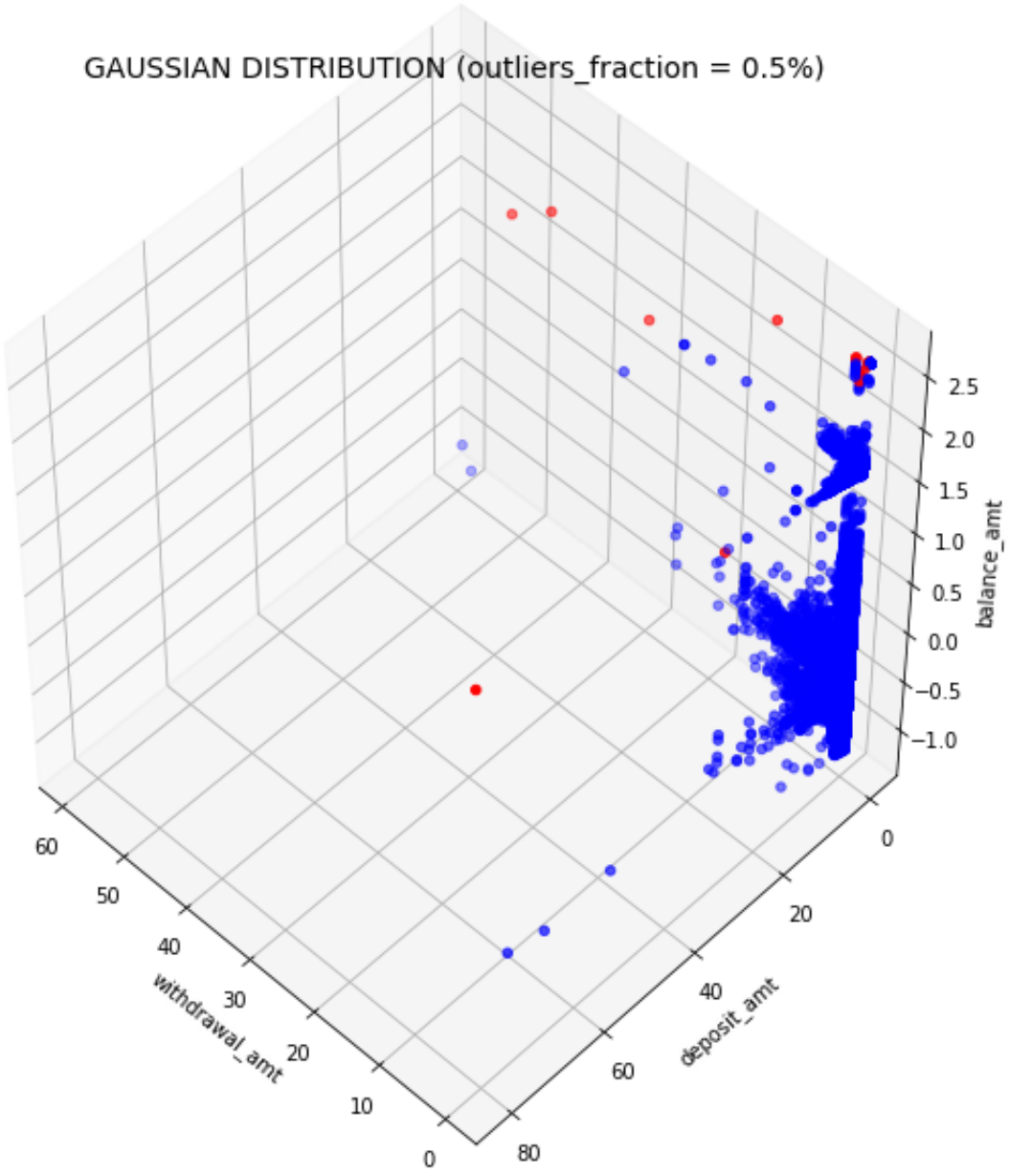
iii. Gaussian Distribution Anomaly Detection (Elliptic Envelope)

```
bank_gauss = bank.drop(columns=['date', 'value_date'], axis=1)
scaler = StandardScaler()
bank_gauss_scaled = pd.DataFrame(scaler.fit_transform(bank_gauss), columns=bank_


outliers_fraction = .005
envelope =  EllipticEnvelope(contamination = outliers_fraction)
X_train = bank_gauss_scaled.values
envelope.fit(X_train)
bank_gauss_scaled['deviation'] = envelope.decision_function(X_train)
bank_gauss_scaled['anomaly_gaussian'] = pd.Series(envelope.predict(X_train)).ap
bank_gauss_scaled = bank_gauss_scaled.fillna(0)
bank_main['anomaly_gaussian_elliptic_envelope'] = bank_gauss_scaled.anomaly_ga
bank_main['anomaly_gaussian_elliptic_envelope'].value_counts(dropna=False)
```

```
0    115620
1       581
Name: anomaly_gaussian_elliptic_envelope, dtype: int64
```

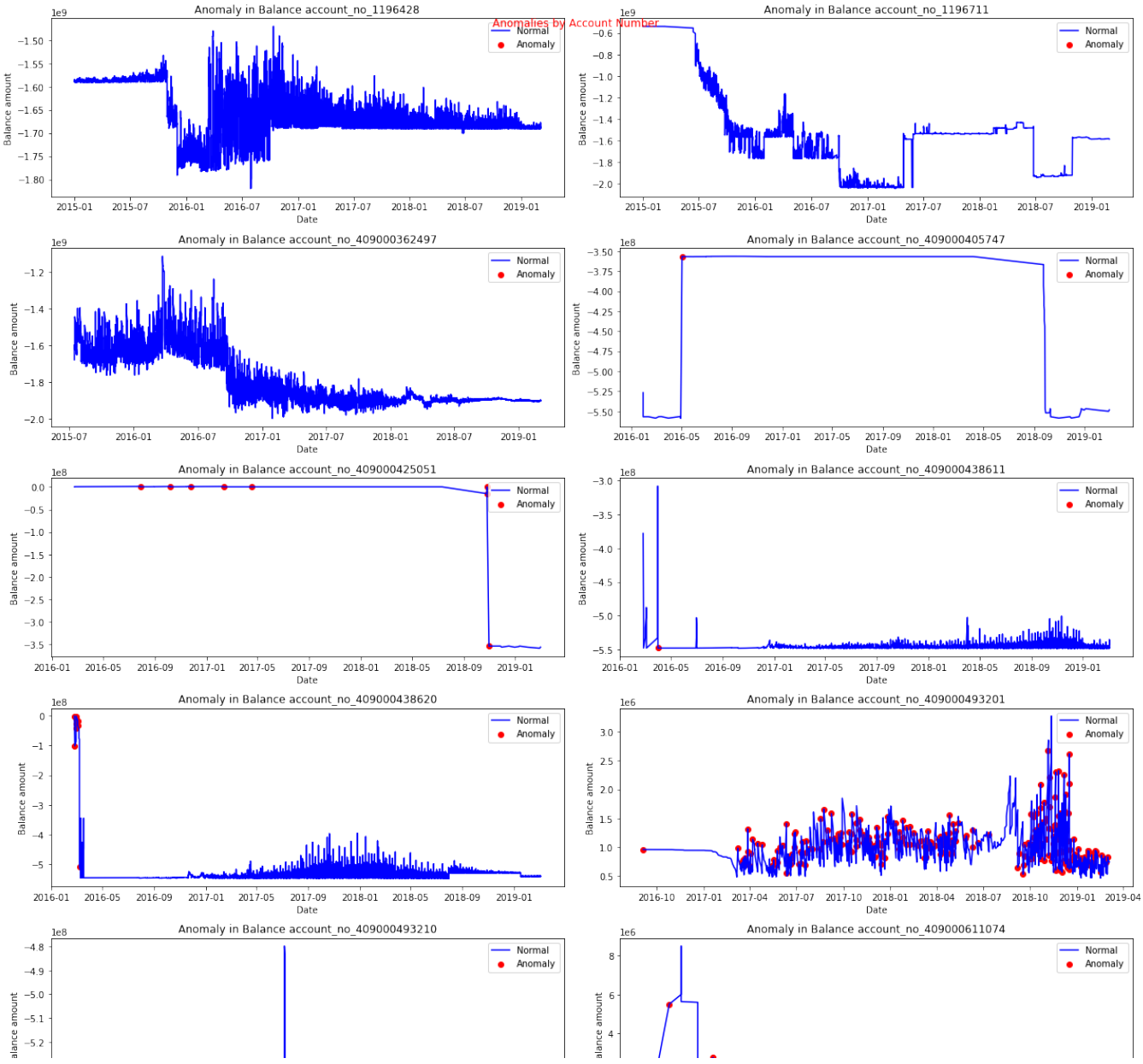
```
labels = bank_main.anomaly_gaussian_elliptic_envelope
colors = {0.0:'blue', 1.0:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(bank_gauss_scaled.iloc[:,3], bank_gauss_scaled.iloc[:,4], bank_gaus
ax.set_title(f'GAUSSIAN DISTRIBUTION (outliers_fraction = {100*outliers_fracti
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

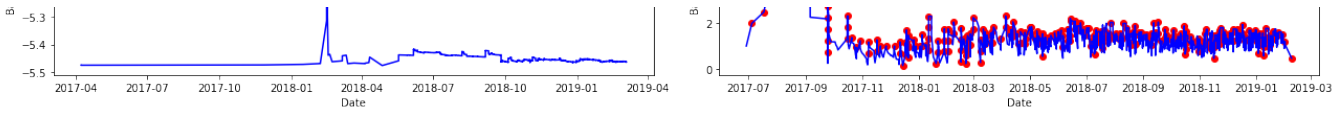
```
Text(0.5, 0, 'balance_amt')
```




```
features = ['account_no_1196428', 'account_no_1196711', 'account_no_4090003624
            'account_no_409000438611', 'account_no_409000438620', 'account_no_
fig, axes = plt.subplots(5,2, sharex=False, figsize=(18, 18))
```

```
fig.suptitle('Anomalies by Account Number', color='r' )

for i in range(5):
    for j in range(2):

        df = bank_main[bank_main[features[2*i + j]]==1]
        a= df.loc[df['anomaly_gaussian_elliptic_envelope']==1, ['date', 'balan

        axes[i,j].plot(df['date'], df['balance_amt'], color='blue', label='Nor
        axes[i,j].scatter(a['date'], a['balance_amt'], color='red', label='Ano
        axes[i,j].set_title(f'Anomaly in Balance {features[2*i + j]}')
        axes[i,j].set_xlabel('Date')
        axes[i,j].set_ylabel('Balance amount')
        axes[i,j].legend()

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



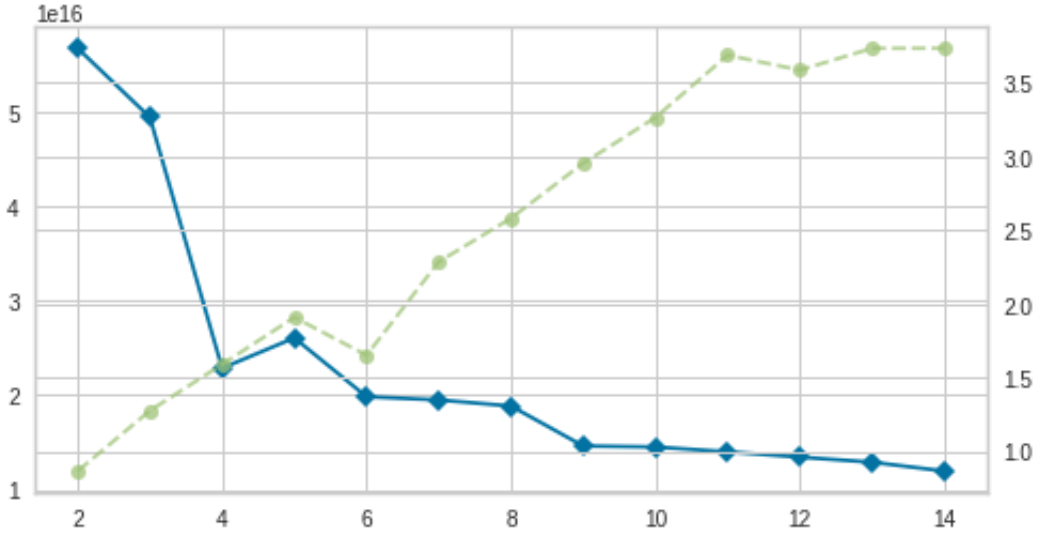


v. Clustering-Based Anomaly Detection

```
from sklearn.cluster import KMeans
from sklearn.preprocessing import StandardScaler
from yellowbrick.cluster import KElbowVisualizer
```

```
bank_clstr = bank.drop(columns=['date', 'value_date'], axis=1)
scaler = StandardScaler()
bank_scaled = scaler.fit_transform(bank_clstr)


# Instantiate the clustering model and visualizer
visualizer = KElbowVisualizer(KMeans(), k=(2,15))
plt.figure(figsize=(8,4)).patch.set_facecolor('xkcd:white')
visualizer.fit(bank_clstr)       # Fit the data to the visualizer
# visualizer.show()       # Finalize and render the figure
```

```
KElbowVisualizer(ax=<matplotlib.axes._subplots.AxesSubplot object at 0x7fa4
                 k=None, metric=None, model=None, timings=True)
```



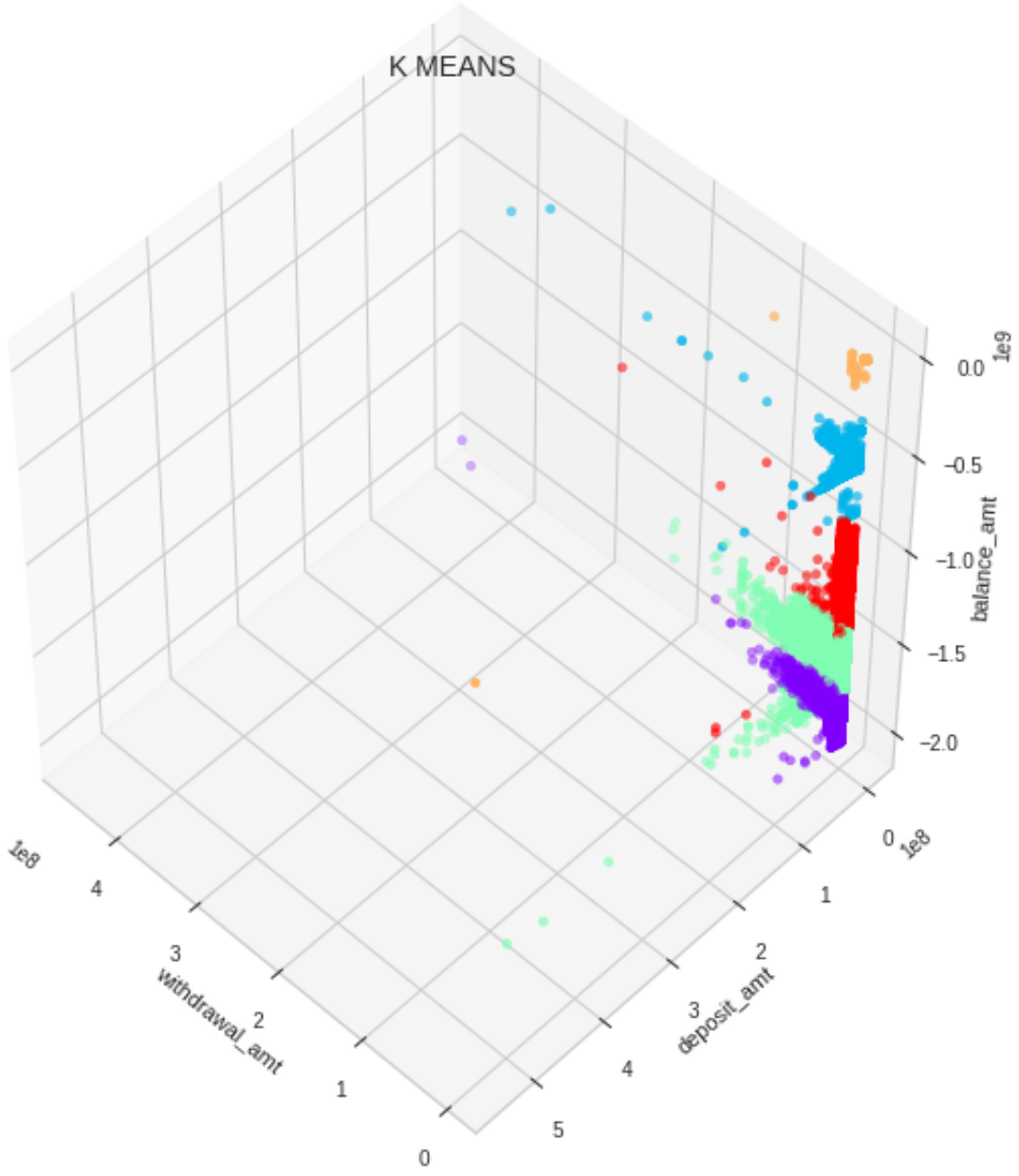

```
kmeans = KMeans(n_clusters=5)
kmeans.fit(bank_clstr)
```

```
KMeans(algorithm='auto', copy_x=True, init='k-means++', max_iter=300,
       n_clusters=5, n_init=10, n_jobs=None, precompute_distances='auto',
       random_state=None, tol=0.0001, verbose=0)
```

Let's visualise labeled clusters.

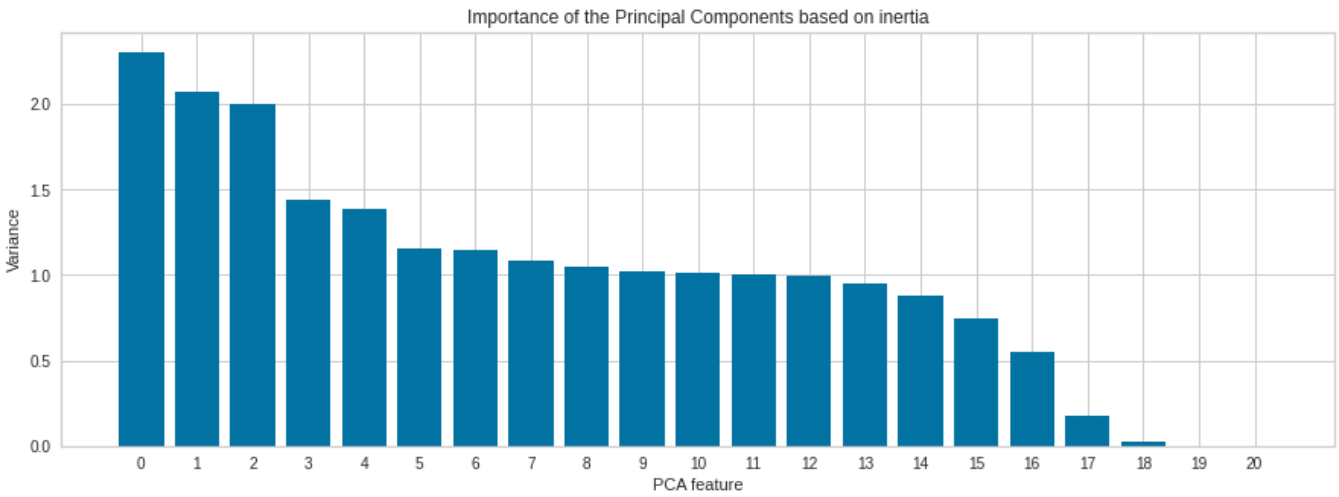
```
labels = kmeans.labels_

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(bank_clstr.iloc[:,3], bank_clstr.iloc[:,4], bank_clstr.iloc[:,5], c=
ax.set_title('K MEANS', fontsize=14)
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```

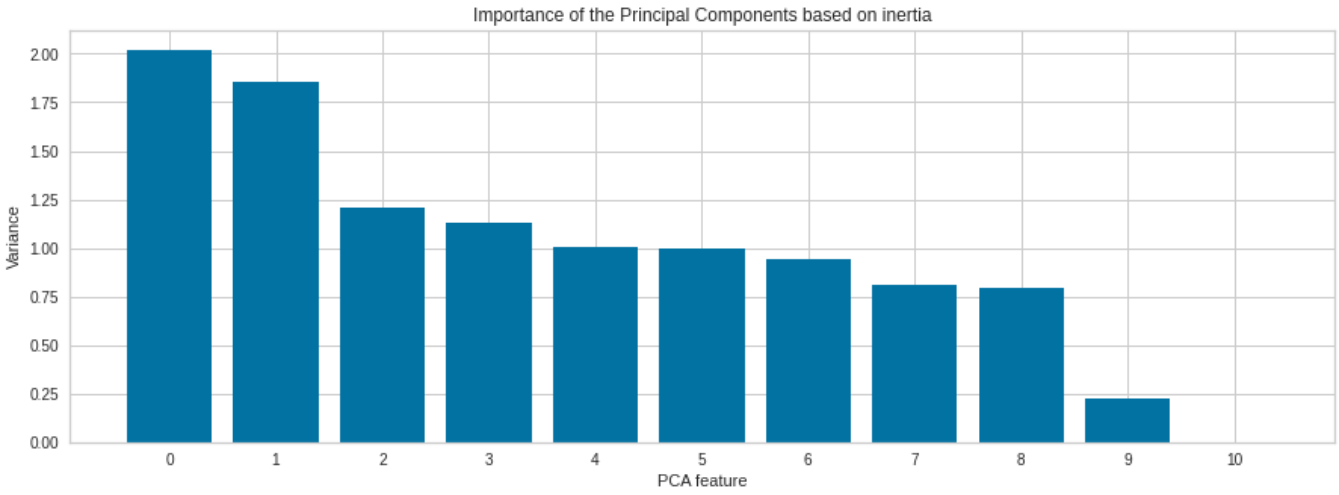


To overcome the curse of dimensionality, we need to figure out which components we want to keep.

```
# Standardize/scale the dataset and apply PCA
from sklearn.decomposition import PCA
from sklearn.pipeline import make_pipeline
# Extract the names of the numerical columns
x = bank_clstr
scaler = StandardScaler()
pca = PCA()
pipeline = make_pipeline(scaler, pca)
pipeline.fit(x)
# Plot the principal components against their inertia
features = range(pca.n_components_)
_ = plt.figure(figsize=(15, 5))
_ = plt.bar(features, pca.explained_variance_)
_ = plt.xlabel('PCA feature')
_ = plt.ylabel('Variance')
_ = plt.xticks(features)
_ = plt.title("Importance of the Principal Components based on inertia")
plt.show()
```



```
bank_gen = bank_clstr[bank_clstr.columns[:11]]

# Extract the names of the numerical columns
x = bank_gen
scaler = StandardScaler()
pca = PCA()
pipeline = make_pipeline(scaler, pca)
pipeline.fit(x)
# Plot the principal components against their inertia
features = range(pca.n_components_)
_ = plt.figure(figsize=(15, 5))
_ = plt.bar(features, pca.explained_variance_)
_ = plt.xlabel('PCA feature')
_ = plt.ylabel('Variance')
_ = plt.xticks(features)
_ = plt.title("Importance of the Principal Components based on inertia")
plt.show()
```



It turns out that even a data frame without customer columns PCA does not help too much in our case.

In K-Means Clustering approach to anomaly detection we calculate the distance between each point and its nearest centroid and the biggest distances are considered as anomaly. We are going to take following steps:

- We assume a proportion of data as outliers (outliers_fraction: proportion of the outliers present in our data set) and calculate number_of_outliers using outliers_fraction.
- We set a threshold as the minimum distance of these outliers.
- After labeling (0:normal, 1:anomaly) anomalies we will visualize them.

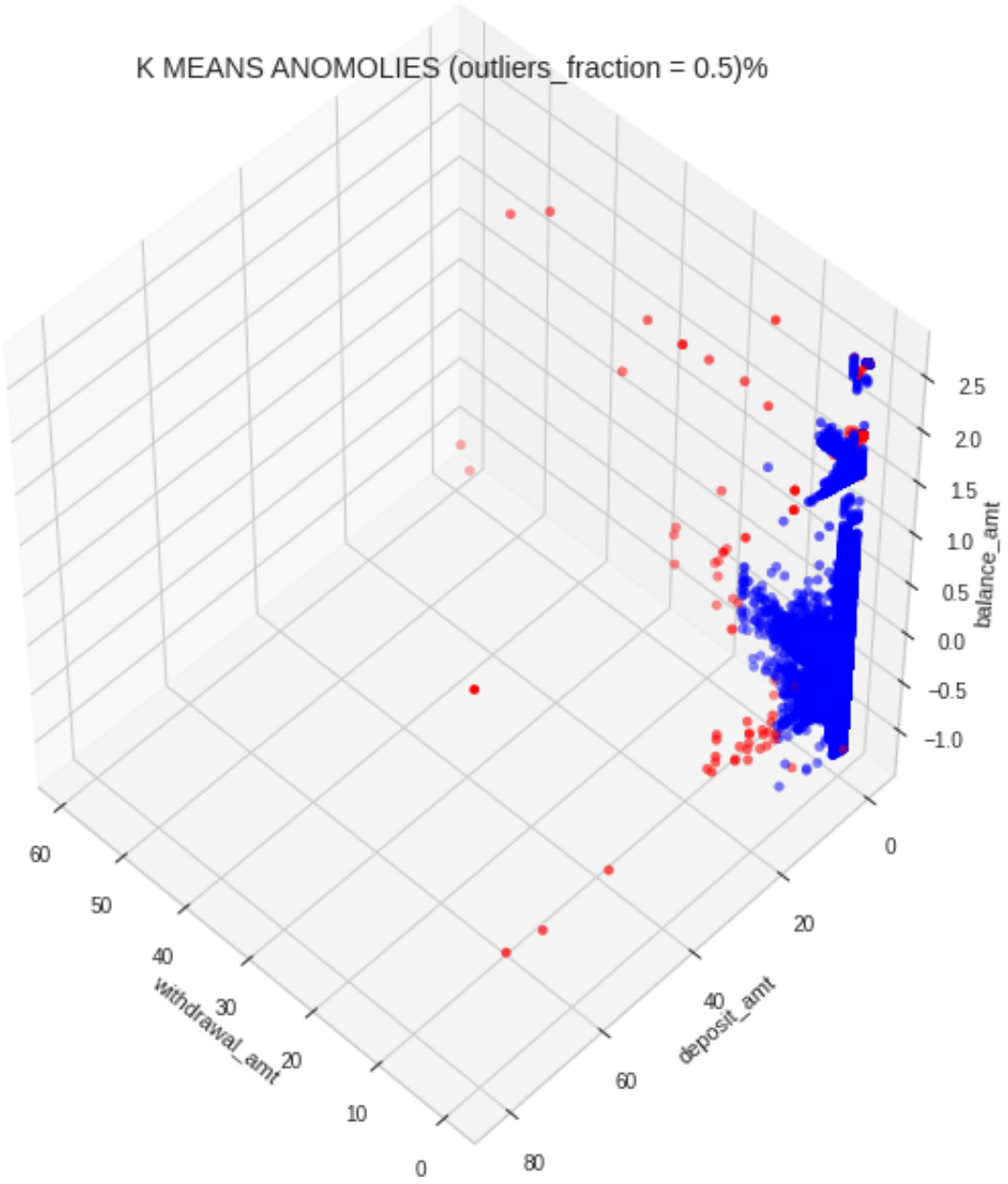
```
def getDistanceByPoint(data, model):
    """
    Function that calculates the distance between a point and centroid of a cl
    returns the distances in pandas series
    """
    distance = []
    for i in range(0,len(data)):
        Xa = np.array(data.loc[i])
        Xb = model.cluster_centers_[model.labels_[i]-1]
        distance.append(np.linalg.norm(Xa-Xb))
    return pd.Series(distance, index=data.index)

bank_scaled = pd.DataFrame(bank_scaled, columns=bank_clstr.columns)
kmeans = KMeans(n_clusters=5)
kmeans.fit(bank_scaled)
labels = kmeans.predict(bank_scaled)
unique_elements, counts_elements = np.unique(labels, return_counts=True)
clusters = np.asarray((unique_elements, counts_elements))

# Assume that 0.5% of the entire data set are anomalies
outliers_fraction = 0.005
# get the distance between each point and its nearest centroid. The biggest di
distance = getDistanceByPoint(bank_scaled, kmeans)
# number of observations that equate to the 0.5% of the entire data set
number_of_outliers = int(outliers_fraction*len(distance))
# Take the minimum of the largest 0.5% of the distances as the threshold
threshold = distance.nlargest(number_of_outliers).min()
# anomaly1 contain the anomaly result of the above method Cluster (0:normal, 1
bank_scaled['anomaly_kmeans'] = (distance >= threshold).astype(int)
```

```
bank_scaled.anomaly_kmeans.value_counts()
```

```
0    115620
1       581
Name: anomaly_kmeans, dtype: int64
```

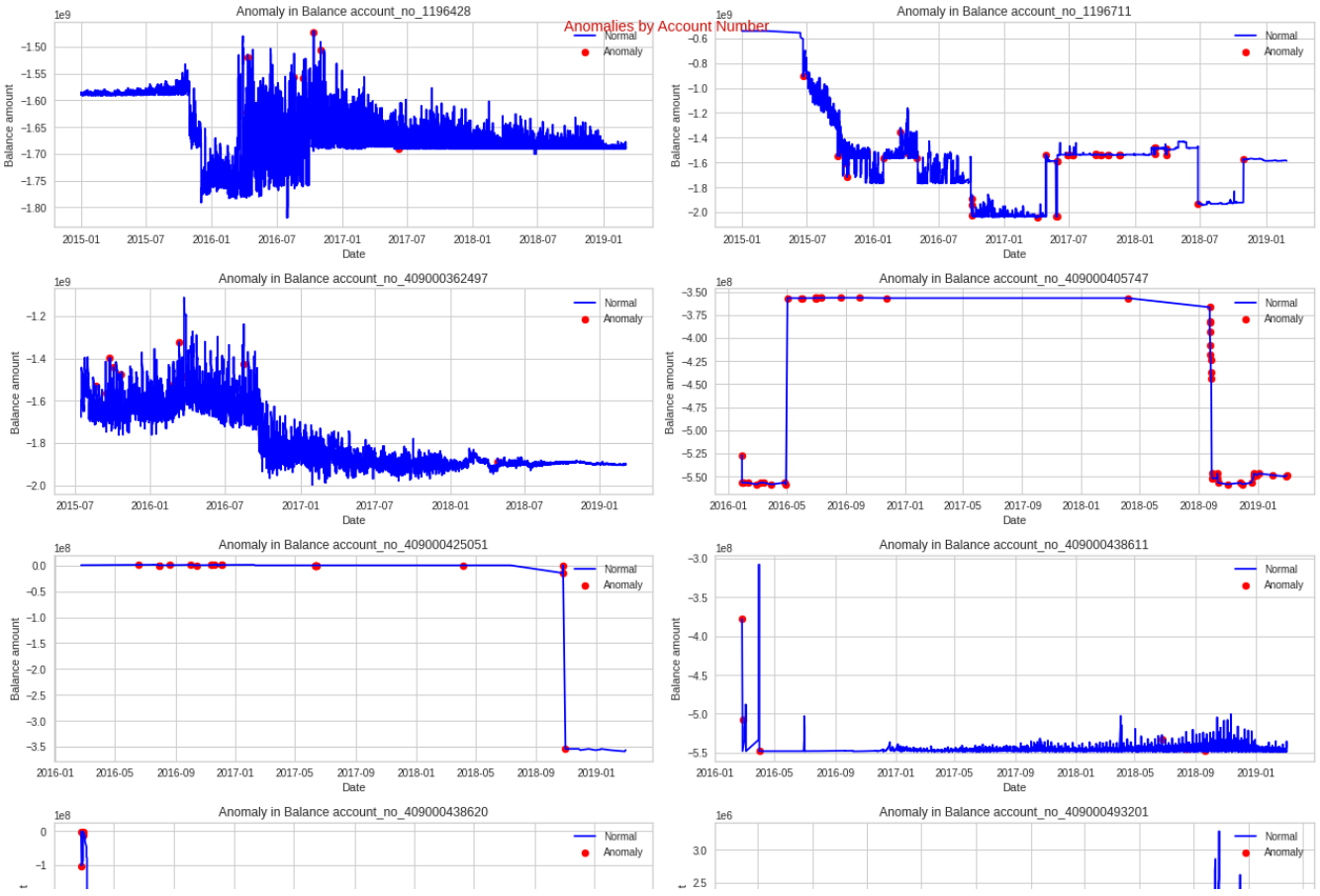
```
labels = bank_scaled.anomaly_kmeans
colors = {0:'blue', 1:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(bank_scaled.iloc[:,3], bank_scaled.iloc[:,4], bank_scaled.iloc[:,5]
ax.set_title(f'K MEANS ANOMOLIES (outliers_fraction = {100*outliers_fraction})%
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

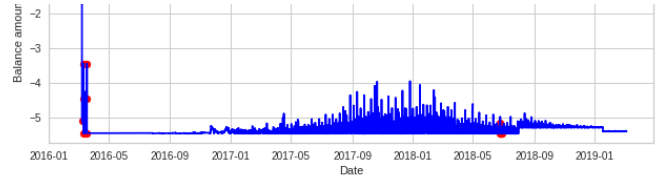
```
Text(0.5, 0, 'balance_amt')
```

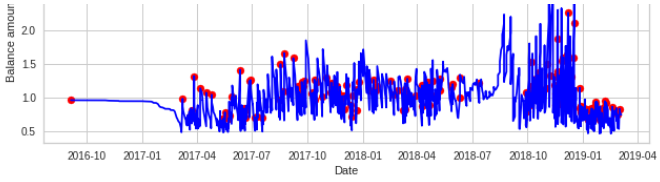


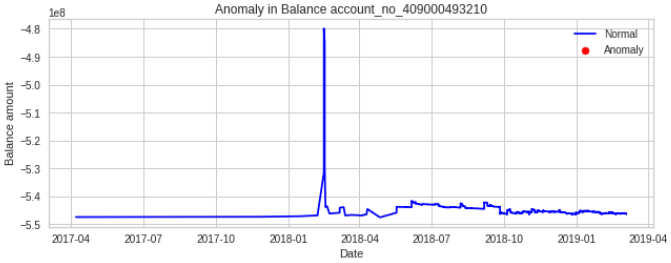

```
bank_main['anomaly_kmeans'] = bank_scaled.anomaly_kmeans
```

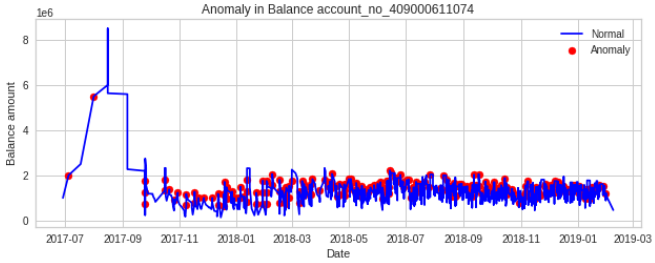
```
# bank_main = bank_clstr.copy()
# bank_main['date'], bank_main['value_date'], bank_main['anomaly_kmeans'] = ba


features = ['account_no_1196428', 'account_no_1196711', 'account_no_4090003624
            'account_no_409000438611', 'account_no_409000438620', 'account_no_
fig, axes = plt.subplots(5,2, sharex=False, figsize=(18, 18))
fig.suptitle('Anomalies by Account Number', color='r' )

for i in range(5):
    for j in range(2):

        df = bank_main[bank_main[features[2*i + j]]==1]
        a= df.loc[df['anomaly_kmeans']==1, ['date', 'balance_amt']]

        axes[i,j].plot(df['date'], df['balance_amt'], color='blue', label='Nor
        axes[i,j].scatter(a['date'], a['balance_amt'], color='red', label='Ano
        axes[i,j].set_title(f'Anomaly in Balance {features[2*i + j]}')
        axes[i,j].set_xlabel('Date')
        axes[i,j].set_ylabel('Balance amount')
        axes[i,j].legend()

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




Balance amour
−2
−3
−4
−5
2016-01
2016-05
2016-09
2017-01
2017-05
2017-09
2018-01
2018-05
2018-09
2019-01
Date


Balance amour
2.0
1.5
1.0
0.5
2016-10
2017-01
2017-04
2017-07
2017-10
2018-01
2018-04
2018-07
2018-10
2019-01
2019-04
Date


Anomaly in Balance account_no_409000493210
1e8
Balance amount
−4.8
−4.9
−5.0
−5.1
−5.2
−5.3
−5.4
−5.5
Normal
Anomaly
2017-04
2017-07
2017-10
2018-01
2018-04
2018-07
2018-10
2019-01
2019-04
Date


Anomaly in Balance account_no_409000611074
1e6
Balance amount
8
6
4
2
0
Normal
Anomaly
2017-07
2017-09
2017-11
2018-01
2018-03
2018-05
2018-07
2018-09
2018-11
2019-01
2019-03
Date

Let's follow the same process, **but this time customer by customer**. To do this, we will split the bank data frame and run the clustering approach for each individual data frame.

```
bank_main.columns
```

```
Index(['date', 'value_date', 'day_diff', 'weekend_date', 'weekend_value_dat
       'withdrawal_amt', 'deposit_amt', 'balance_amt',
       'withdrawal_over_balance', 'deposit_over_balance',
       'details_null_penalty', 'details_numbers_penalty', 'cheque_penalty',
       'account_no_1196428', 'account_no_1196711', 'account_no_409000362497
       'account_no_409000405747', 'account_no_409000425051',
       'account_no_409000438611', 'account_no_409000438620',
       'account_no_409000493201', 'account_no_409000493210',
       'account_no_409000611074', 'anomaly_isolation_forest',
       'anomaly_one_class_svm', 'anomaly_gaussian_elliptic_envelope',
       'anomaly_kmeans'],
      dtype='object')
```

```
bank_main['anomaly_sum_1'] = bank_main.anomaly_kmeans + bank_main.anomaly_isol
bank_main.anomaly_sum_1.value_counts()
```

```
0    114438
1      1128
2       477
3       135
4        23
Name: anomaly_sum_1, dtype: int64
```

4. Anomaly Detection by Account Number

In this section, we will analyze each account number independently.

```
accounts = ['1196428', '409000362497', '409000438620', '1196711', '40900049321
```

```
acc1, acc2, acc3, acc4, acc5, acc6, acc7, acc8, acc9, acc10  = bank_premodel[ba
    bank_premodel[bank_premodel.account_no == accounts[1]].drop('account_no', a
    bank_premodel[bank_premodel.account_no == accounts[3]].drop('account_no', a
    bank_premodel[bank_premodel.account_no == accounts[5]].drop('account_no', a
    bank_premodel[bank_premodel.account_no == accounts[7]].drop('account_no', a
    bank_premodel[bank_premodel.account_no == accounts[9]].drop('account_no', a
df_list = [acc1, acc2, acc3, acc4, acc5, acc6, acc7, acc8, acc9, acc10]
```

i. Isolation Forest Anomaly Detection

(I) Isolation Forest account_no: 1196428

```
acc1_iso = acc1.copy()
scaler = StandardScaler()
acc1_iso_scaled = pd.DataFrame(scaler.fit_transform(acc1_iso[acc1.columns[2:]]))
acc1_iso_scaled.set_index(acc1_iso.index, drop=True, inplace=True)
acc1_iso_scaled.head(3)
```

	day_diff	weekend_date	weekend_value_date	withdrawal_amt	deposit_ar
37582	-0.009703	-0.327498	-0.327574	-0.363895	-0.0352
37583	-0.009703	-0.327498	-0.327574	-0.363895	-0.1051
37584	-0.009703	-0.327498	-0.327574	-0.363895	-0.2422

```
outliers_fraction = .005
model = IsolationForest(contamination=outliers_fraction)
model.fit(acc1_iso_scaled)
```

```
IsolationForest(behaviour='deprecated', bootstrap=False, contamination=0.00
                max_features=1.0, max_samples='auto', n_estimators=100,
                n_jobs=None, random_state=None, verbose=0, warm_start=False
```

```
acc1_iso_scaled['anomaly_iso'] = pd.Series(model.predict(acc1_iso_scaled)).app
acc1_iso['anomaly_iso'] = acc1_iso_scaled['anomaly_iso']
acc1_iso_scaled['anomaly_iso'].value_counts()
```

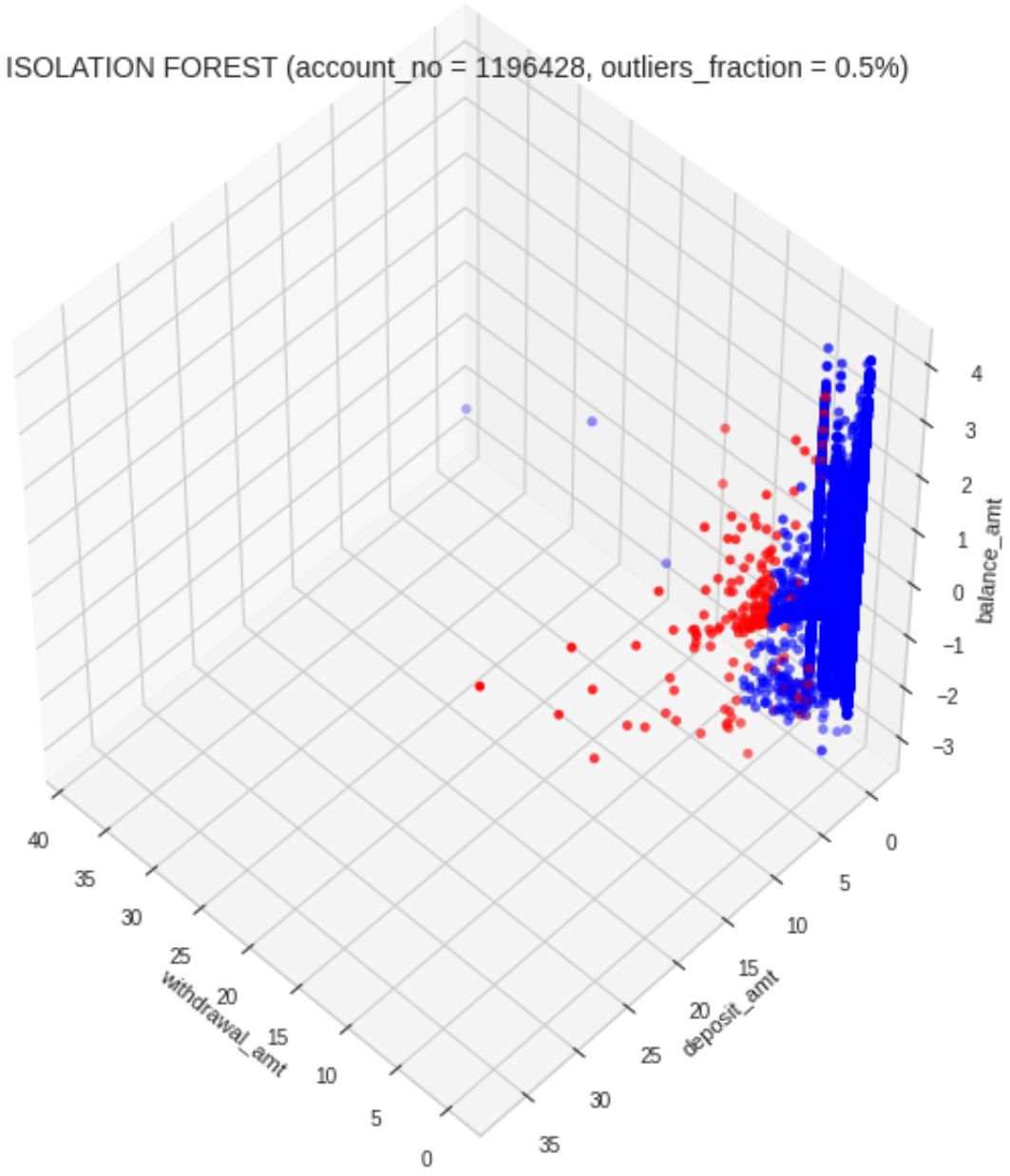
```
0    48545
1      234
Name: anomaly_iso, dtype: int64
```

```
bank_main['iso_1'] = 0
bank_main.loc[acc1_iso_scaled.index,'iso_1'] = acc1_iso_scaled['anomaly_iso']
bank_main['iso_1'].value_counts()
```

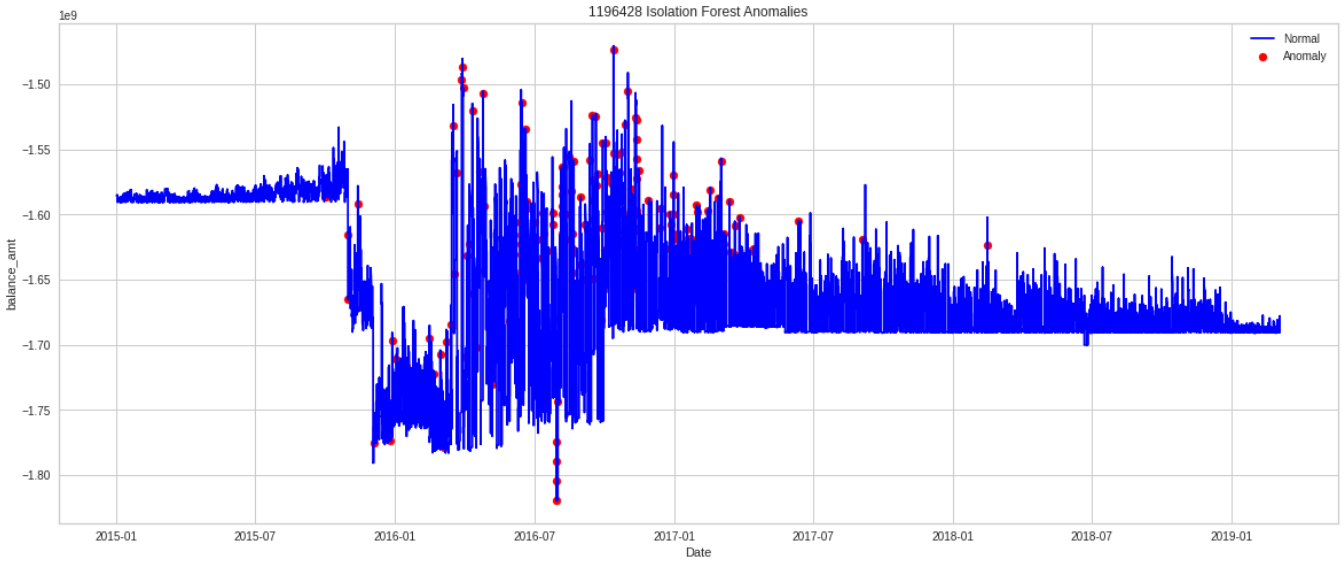
```
0    115967
1       234
Name: iso_1, dtype: int64
```

```
labels = acc1_iso_scaled.anomaly_iso
colors = {0:'blue', 1:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc1_iso_scaled.iloc[:,3], acc1_iso_scaled.iloc[:,4], acc1_iso_scal
ax.set_title(f'ISOLATION FOREST (account_no = {accounts[0]}, outliers_fraction
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
df = acc1_iso.copy()
a= df.loc[df['anomaly_iso']==1, ['date', 'balance_amt']]
plt.figure(figsize=(20,8))
plt.plot(df['date'], df['balance_amt'], color='blue', label='Normal')
plt.scatter(a['date'], a['balance_amt'], color='red', label='Anomaly')
plt.title(f'{accounts[0]} Isolation Forest Anomalies')
plt.xlabel('Date')
plt.ylabel('balance_amt')
plt.legend()
plt.show()
```



(II) Isolation Forest account_no: 409000362497

```
acc2_iso = acc2.copy()
scaler = StandardScaler()
acc2_iso_scaled = pd.DataFrame(scaler.fit_transform(acc2_iso[acc2.columns[2:]]))
acc2_iso_scaled.set_index(acc2_iso.index, drop=True, inplace=True)
acc2_iso_scaled.head(3)
```

	day_diff	weekend_date	weekend_value_date	withdrawal_amt	deposit_ar
86361	-0.020357	-0.286669	-0.286463	-0.297246	1.00303
86362	-0.020357	-0.286669	-0.286463	-0.297246	1.00303
86363	-0.020357	-0.286669	-0.286463	-0.297246	1.00303

```
outliers_fraction = .005
model = IsolationForest(contamination=outliers_fraction)
model.fit(acc2_iso_scaled)
```

```
IsolationForest(behaviour='deprecated', bootstrap=False, contamination=0.00
                max_features=1.0, max_samples='auto', n_estimators=100,
                n_jobs=None, random_state=None, verbose=0, warm_start=False
```

```
acc2_iso_scaled['anomaly_iso'] = pd.Series(model.predict(acc2_iso_scaled)).app
acc2_iso['anomaly_iso'] = acc2_iso_scaled['anomaly_iso']
acc2_iso_scaled['anomaly_iso'].value_counts()
```

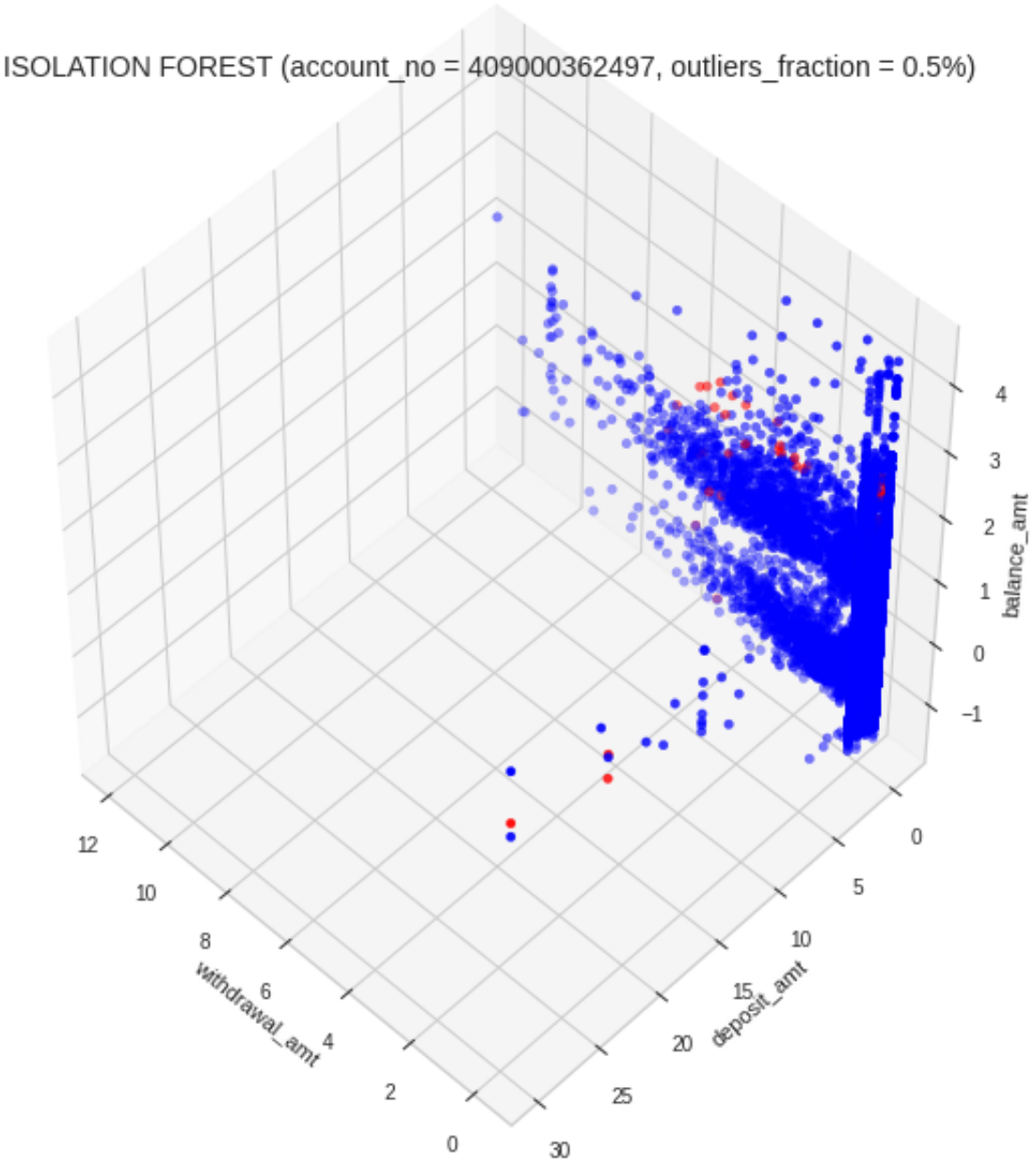
```
0    29690
1      150
Name: anomaly_iso, dtype: int64
```

```
bank_main['iso_2'] = 0
bank_main.loc[acc2_iso_scaled.index,'iso_2'] = acc2_iso_scaled['anomaly_iso']
bank_main['iso_2'].value_counts()
```

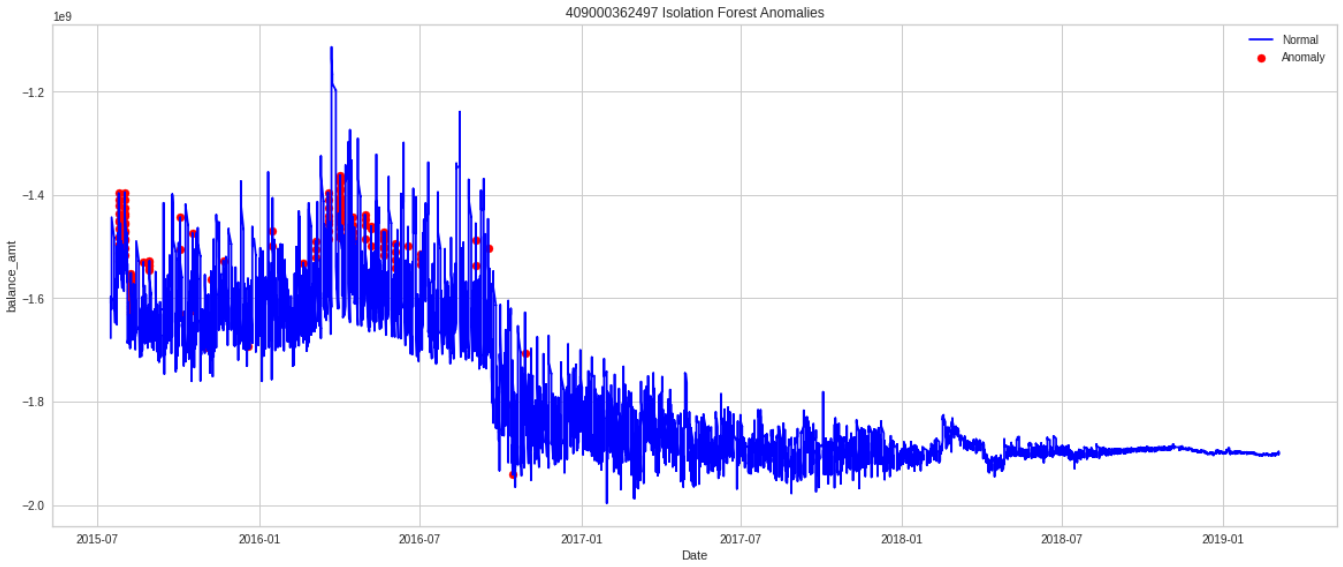
```
0    116051
1       150
Name: iso_2, dtype: int64
```

```
labels = acc2_iso_scaled.anomaly_iso
colors = {0:'blue', 1:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc2_iso_scaled.iloc[:,3], acc2_iso_scaled.iloc[:,4], acc2_iso_scal
ax.set_title(f'ISOLATION FOREST (account_no = {accounts[1]}, outliers_fraction
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
df = acc2_iso.copy()
a= df.loc[df['anomaly_iso']==1, ['date', 'balance_amt']]
plt.figure(figsize=(20,8))
plt.plot(df['date'], df['balance_amt'], color='blue', label='Normal')
plt.scatter(a['date'], a['balance_amt'], color='red', label='Anomaly')
plt.title(f'{accounts[1]} Isolation Forest Anomalies')
plt.xlabel('Date')
plt.ylabel('balance_amt')
plt.legend()
plt.show()
```



(III) Isolation Forest account_no: 409000438620

```
acc3_iso = acc3.copy()
scaler = StandardScaler()
acc3_iso_scaled = pd.DataFrame(scaler.fit_transform(acc3_iso[acc3.columns[2:]]))
acc3_iso_scaled.set_index(acc3_iso.index, drop=True, inplace=True)
acc3_iso_scaled.head(3)
```

	day_diff	weekend_date	weekend_value_date	withdrawal_amt	deposit_ar
13592	0.0	-0.310493	-0.310493	-0.199596	68.5563
13593	0.0	-0.310493	-0.310493	15.416558	-0.1612
13594	0.0	-0.310493	-0.310493	-0.199596	1.7307

```
outliers_fraction = .01
model = IsolationForest(contamination=outliers_fraction)
model.fit(acc3_iso_scaled)
```

```
IsolationForest(behaviour='deprecated', bootstrap=False, contamination=0.01
                max_features=1.0, max_samples='auto', n_estimators=100,
                n_jobs=None, random_state=None, verbose=0, warm_start=False
```

```
acc3_iso_scaled['anomaly_iso'] = pd.Series(model.predict(acc3_iso_scaled)).app
acc3_iso['anomaly_iso'] = acc3_iso_scaled['anomaly_iso']
acc3_iso_scaled['anomaly_iso'].value_counts()
```

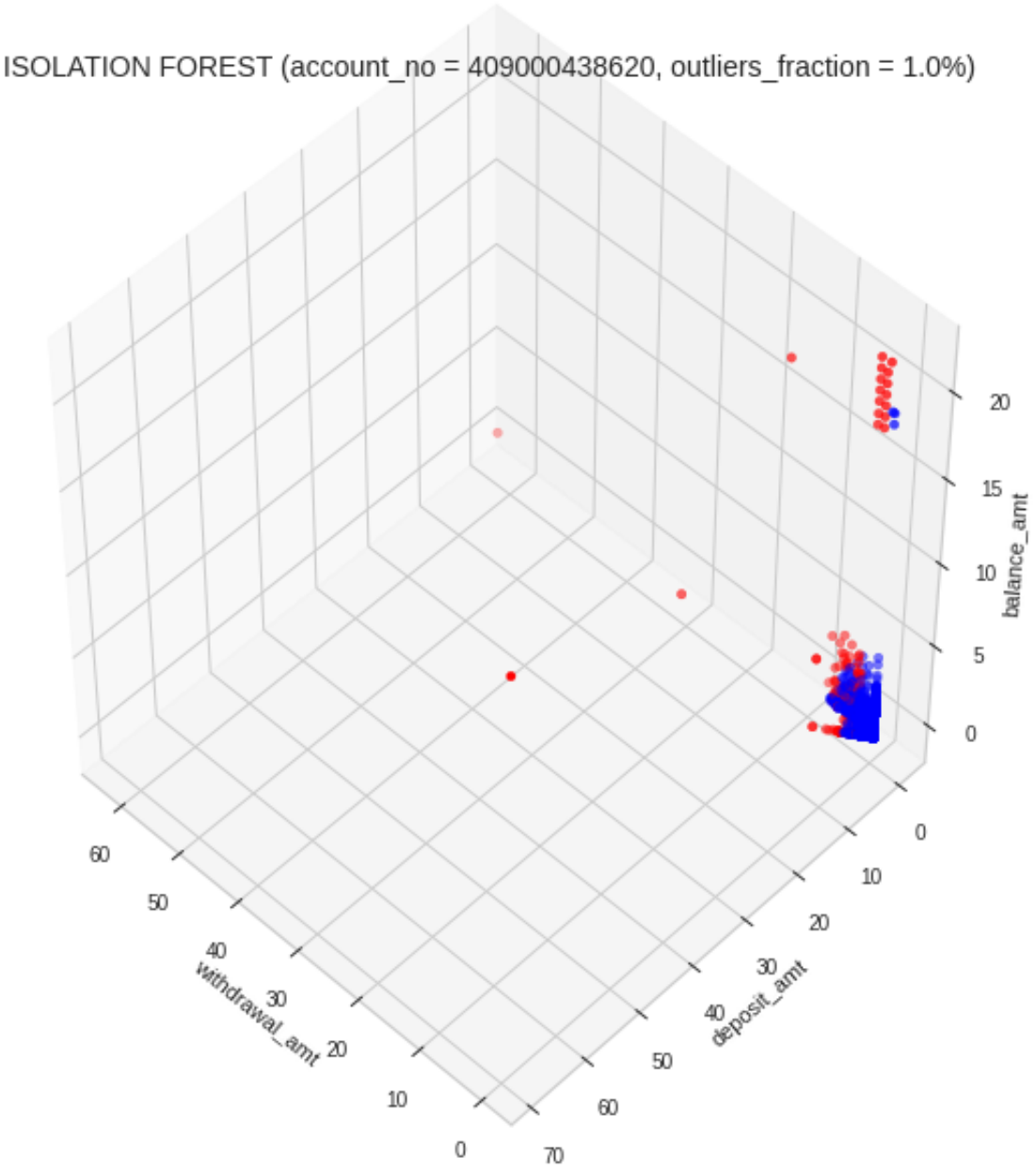
```
0    13319
1      135
Name: anomaly_iso, dtype: int64
```

```
bank_main['iso_3'] = 0
bank_main.loc[acc3_iso_scaled.index,'iso_3'] = acc3_iso_scaled['anomaly_iso']
bank_main['iso_3'].value_counts()
```

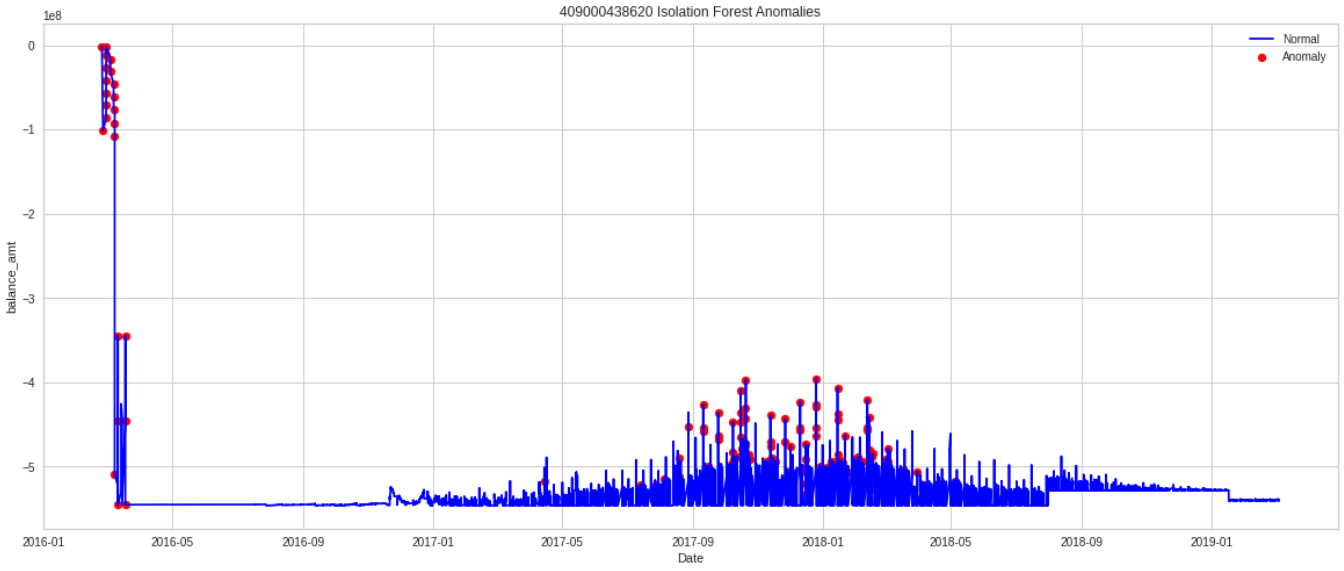
```
0    116066
1       135
Name: iso_3, dtype: int64
```

```
labels = acc3_iso_scaled.anomaly_iso
colors = {0:'blue', 1:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc3_iso_scaled.iloc[:,3], acc3_iso_scaled.iloc[:,4], acc3_iso_scal
ax.set_title(f'ISOLATION FOREST (account_no = {accounts[2]}, outliers_fraction
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
df = acc3_iso.copy()
a= df.loc[df['anomaly_iso']==1, ['date', 'balance_amt']]
plt.figure(figsize=(20,8))
plt.plot(df['date'], df['balance_amt'], color='blue', label='Normal')
plt.scatter(a['date'], a['balance_amt'], color='red', label='Anomaly')
plt.title(f'{accounts[2]} Isolation Forest Anomalies')
plt.xlabel('Date')
plt.ylabel('balance_amt')
plt.legend()
plt.show()
```



(IV) Isolation Forest account_no: 1196711

```
acc4_iso = acc4.copy()
scaler = StandardScaler()
acc4_iso_scaled = pd.DataFrame(scaler.fit_transform(acc4_iso[acc4.columns[2:]]))
acc4_iso_scaled.set_index(acc4_iso.index, drop=True, inplace=True)
acc4_iso_scaled.head(3)
```

	day_diff	weekend_date	weekend_value_date	withdrawal_amt	deposit_ar
27046	-0.06111	-0.308943	-0.309496	-0.415321	-0.4182(
27047	-0.06111	-0.308943	-0.309496	-0.415321	-0.4184(
27048	-0.06111	-0.308943	-0.309496	-0.415321	-0.4183(

```
outliers_fraction = .01
model = IsolationForest(contamination=outliers_fraction)
model.fit(acc4_iso_scaled)
```

```
IsolationForest(behaviour='deprecated', bootstrap=False, contamination=0.01
                max_features=1.0, max_samples='auto', n_estimators=100,
                n_jobs=None, random_state=None, verbose=0, warm_start=False
```

```
acc4_iso_scaled['anomaly_iso'] = pd.Series(model.predict(acc4_iso_scaled)).app
acc4_iso['anomaly_iso'] = acc4_iso_scaled['anomaly_iso']
acc4_iso_scaled['anomaly_iso'].value_counts()
```

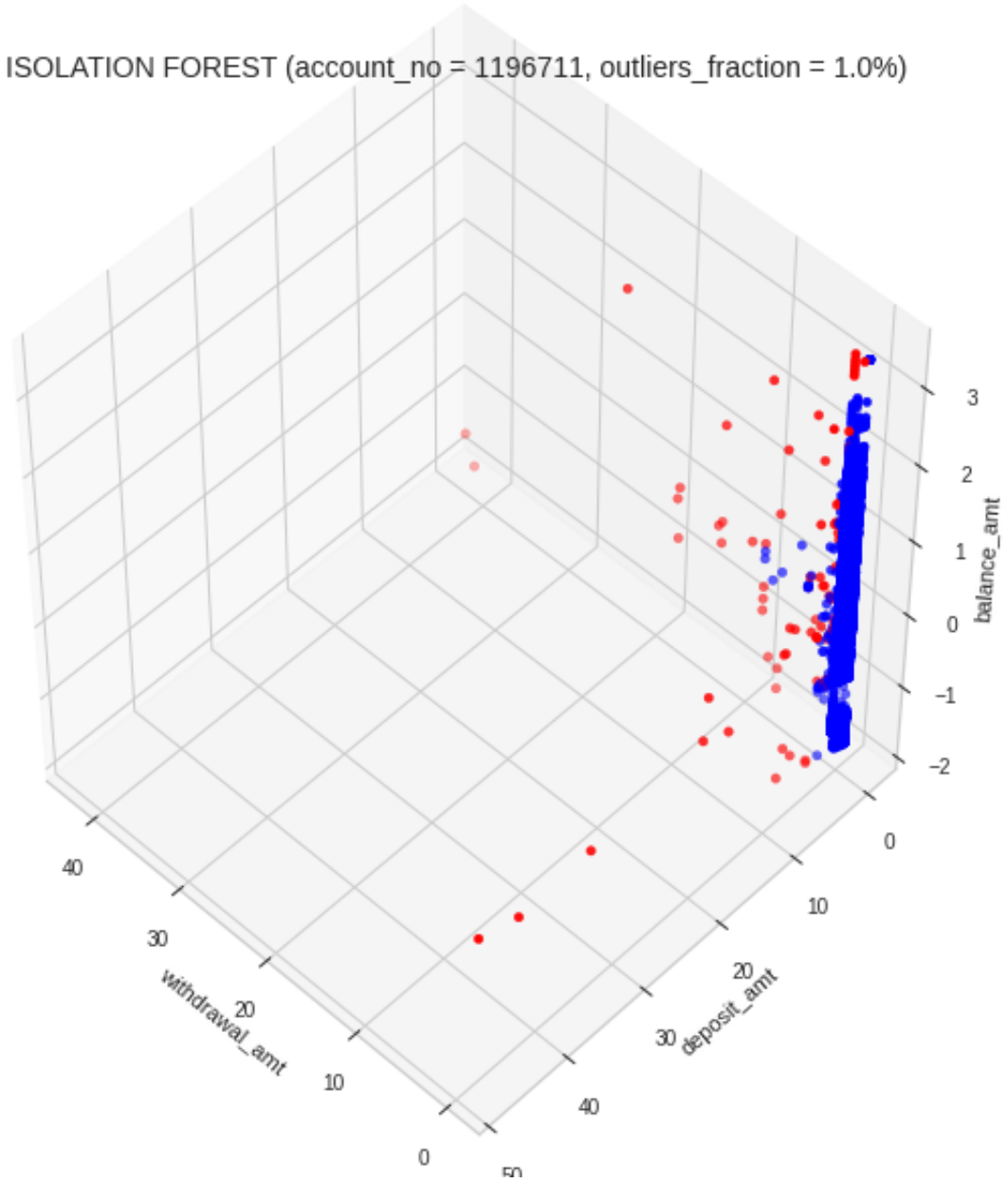
```
0    10430
1      106
Name: anomaly_iso, dtype: int64
```

```
bank_main['iso_4'] = 0
bank_main.loc[acc4_iso_scaled.index,'iso_4'] = acc4_iso_scaled['anomaly_iso']
bank_main['iso_4'].value_counts()
```

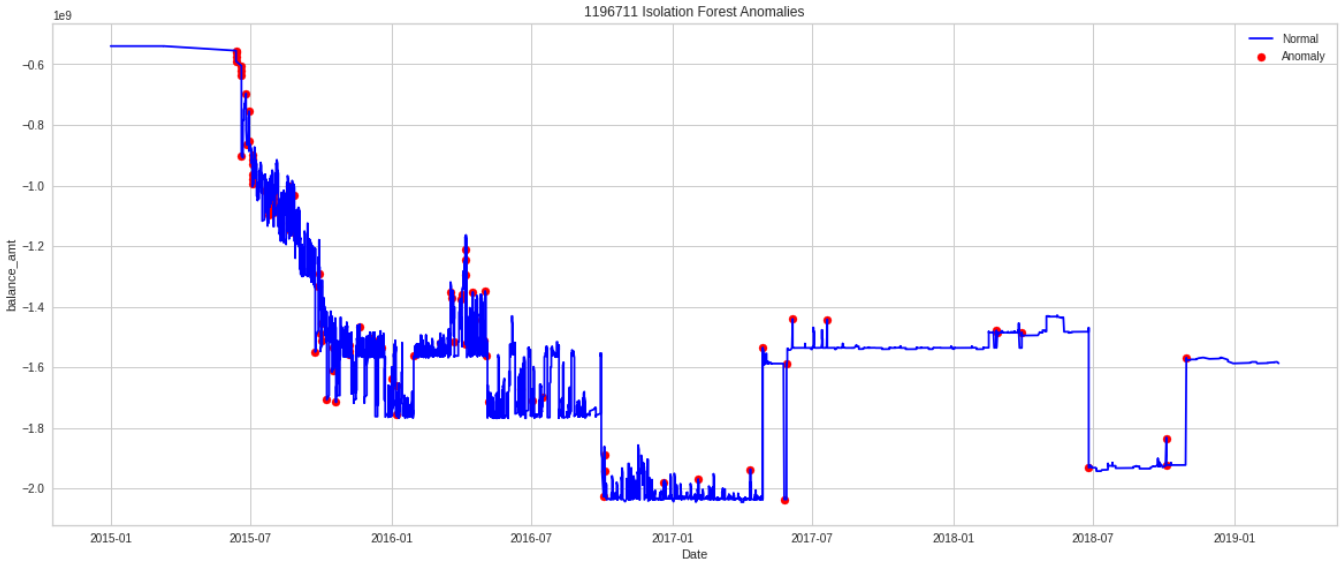
```
0    116095
1       106
Name: iso_4, dtype: int64
```

```
labels = acc4_iso_scaled.anomaly_iso
colors = {0:'blue', 1:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc4_iso_scaled.iloc[:,3], acc4_iso_scaled.iloc[:,4], acc4_iso_scal
ax.set_title(f'ISOLATION FOREST (account_no = {accounts[3]}, outliers_fraction
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
df = acc4_iso.copy()
a= df.loc[df['anomaly_iso']==1, ['date', 'balance_amt']]
plt.figure(figsize=(20,8))
plt.plot(df['date'], df['balance_amt'], color='blue', label='Normal')
plt.scatter(a['date'], a['balance_amt'], color='red', label='Anomaly')
plt.title(f'{accounts[3]} Isolation Forest Anomalies')
plt.xlabel('Date')
plt.ylabel('balance_amt')
plt.legend()
plt.show()
```



(V) Isolation Forest account_no: 409000493210

```
acc5_iso = acc5.copy()
scaler = StandardScaler()
acc5_iso_scaled = pd.DataFrame(scaler.fit_transform(acc5_iso[acc5.columns[2:]]))
acc5_iso_scaled.set_index(acc5_iso.index, drop=True, inplace=True)
acc5_iso_scaled.head(3)
```

	day_diff	weekend_date	weekend_value_date	withdrawal_amt	deposit_amt
7578	0.0	-0.249713	-0.249713	-0.042609	1.20359
7579	0.0	-0.249713	-0.249713	-0.042227	-0.04235
7580	0.0	-0.249713	-0.249713	-0.042555	-0.04235

```
outliers_fraction = .01
model = IsolationForest(contamination=outliers_fraction)
model.fit(acc5_iso_scaled)
```

```
IsolationForest(behaviour='deprecated', bootstrap=False, contamination=0.01
                max_features=1.0, max_samples='auto', n_estimators=100,
                n_jobs=None, random_state=None, verbose=0, warm_start=False
```

```
acc5_iso_scaled['anomaly_iso'] = pd.Series(model.predict(acc5_iso_scaled)).app
acc5_iso['anomaly_iso'] = acc5_iso_scaled['anomaly_iso']
acc5_iso_scaled['anomaly_iso'].value_counts()
```

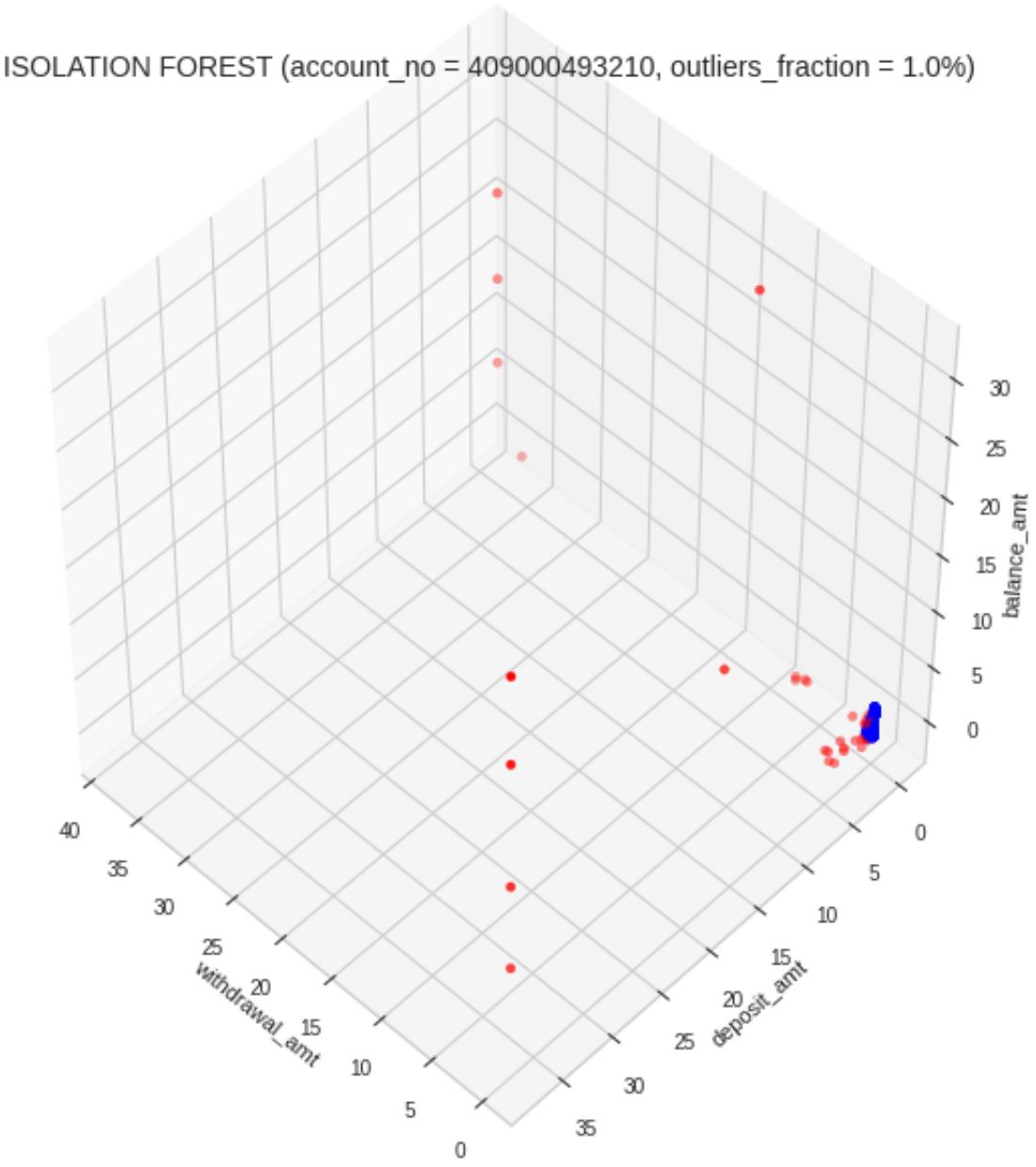
```
0    5953
1      61
Name: anomaly_iso, dtype: int64
```

```
bank_main['iso_5'] = 0
bank_main.loc[acc5_iso_scaled.index,'iso_5'] = acc5_iso_scaled['anomaly_iso']
bank_main['iso_5'].value_counts()
```

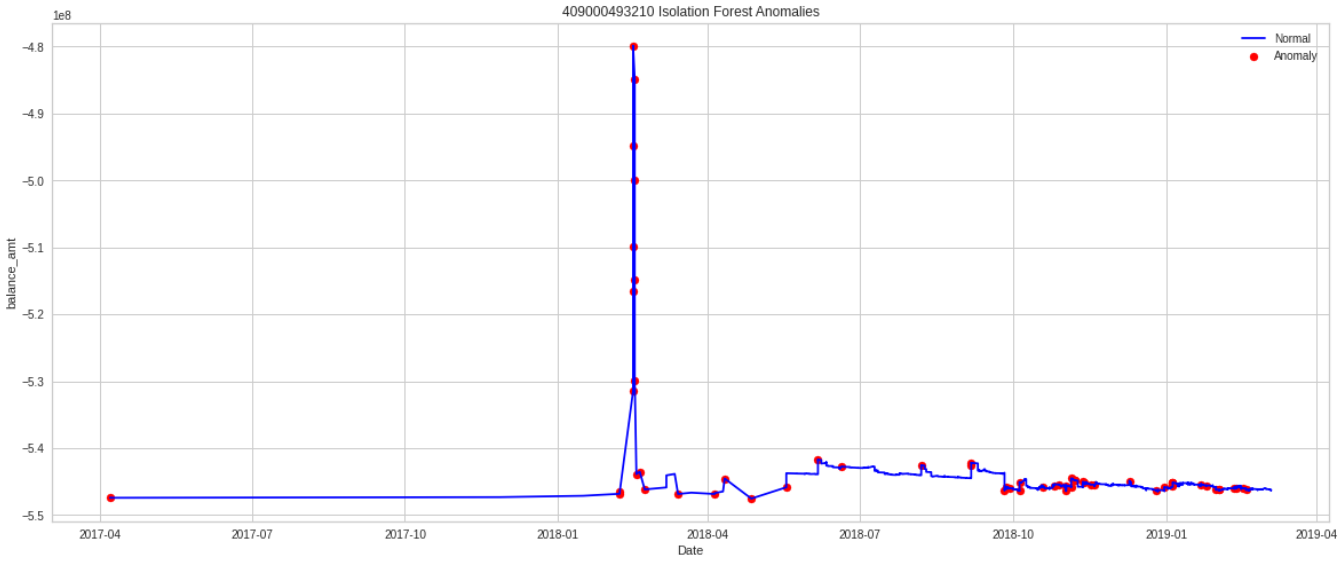
```
0    116140
1        61
Name: iso_5, dtype: int64
```

```
labels = acc5_iso_scaled.anomaly_iso
colors = {0:'blue', 1:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc5_iso_scaled.iloc[:,3], acc5_iso_scaled.iloc[:,4], acc5_iso_scal
ax.set_title(f'ISOLATION FOREST (account_no = {accounts[4]}, outliers_fraction
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
df = acc5_iso.copy()
a= df.loc[df['anomaly_iso']==1, ['date', 'balance_amt']]
plt.figure(figsize=(20,8))
plt.plot(df['date'], df['balance_amt'], color='blue', label='Normal')
plt.scatter(a['date'], a['balance_amt'], color='red', label='Anomaly')
plt.title(f'{accounts[4]} Isolation Forest Anomalies')
plt.xlabel('Date')
plt.ylabel('balance_amt')
plt.legend()
plt.show()
```



(VI) Isolation Forest account_no: 409000438611

```
acc6_iso = acc6.copy()
scaler = StandardScaler()
acc6_iso_scaled = pd.DataFrame(scaler.fit_transform(acc6_iso[acc6.columns[2:]]))
acc6_iso_scaled.set_index(acc6_iso.index, drop=True, inplace=True)
acc6_iso_scaled.head(3)
```

	day_diff	weekend_date	weekend_value_date	withdrawal_amt	deposit_amt
2990	0.0	-0.280204	-0.280204	-0.217132	52.87383
2991	0.0	-0.280204	-0.280204	27.304861	-0.32047
2992	0.0	-0.280204	-0.280204	8.251173	-0.32047

```
outliers_fraction = .01
model = IsolationForest(contamination=outliers_fraction)
model.fit(acc6_iso_scaled)
```

```
IsolationForest(behaviour='deprecated', bootstrap=False, contamination=0.01
                max_features=1.0, max_samples='auto', n_estimators=100,
                n_jobs=None, random_state=None, verbose=0, warm_start=False
```

```
acc6_iso_scaled['anomaly_iso'] = pd.Series(model.predict(acc6_iso_scaled)).app
acc6_iso['anomaly_iso'] = acc6_iso_scaled['anomaly_iso']
acc6_iso_scaled['anomaly_iso'].value_counts()
```

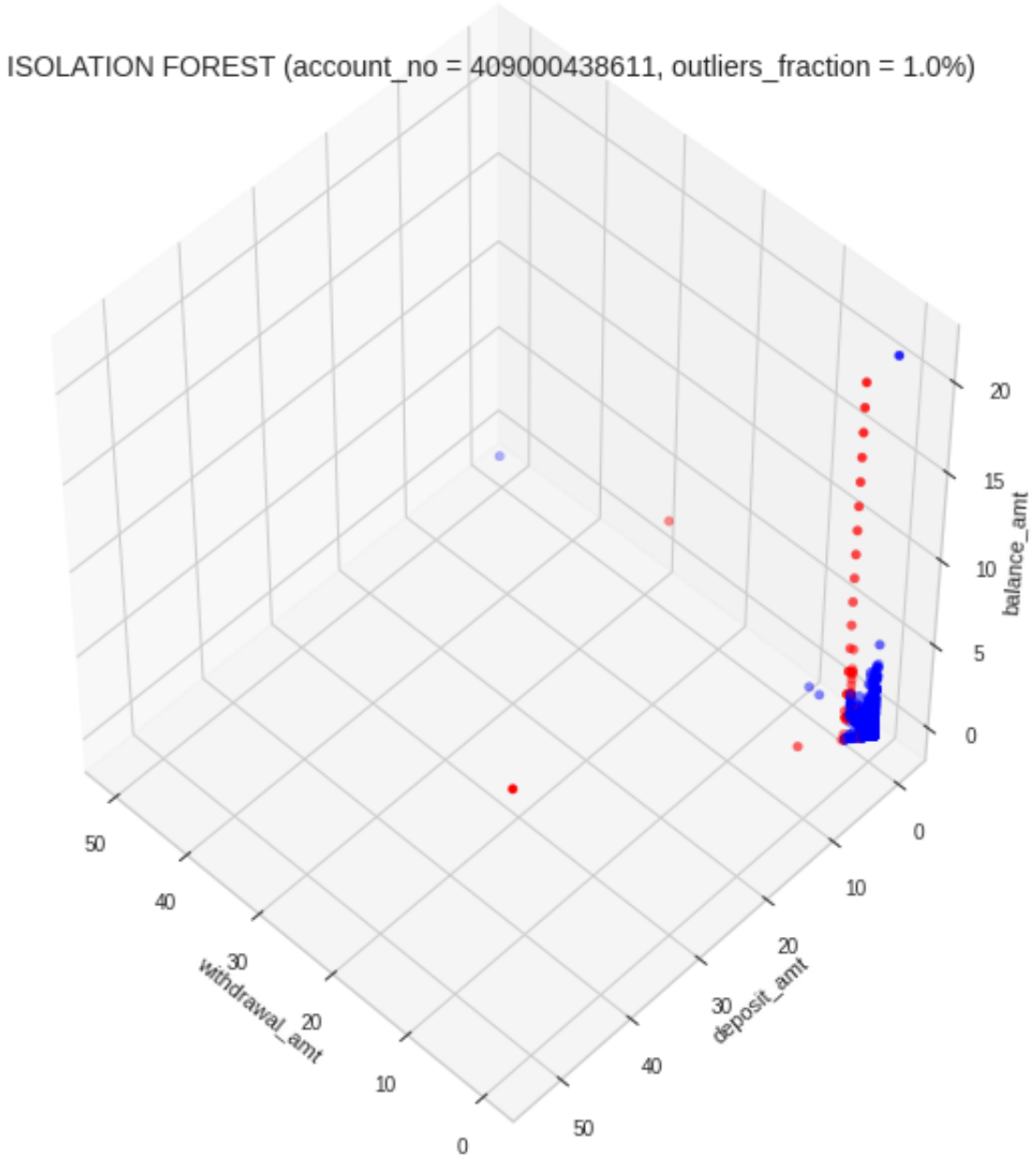
```
0    4542
1      46
Name: anomaly_iso, dtype: int64
```

```
bank_main['iso_6'] = 0
bank_main.loc[acc6_iso_scaled.index,'iso_6'] = acc6_iso_scaled['anomaly_iso']
bank_main['iso_6'].value_counts()
```

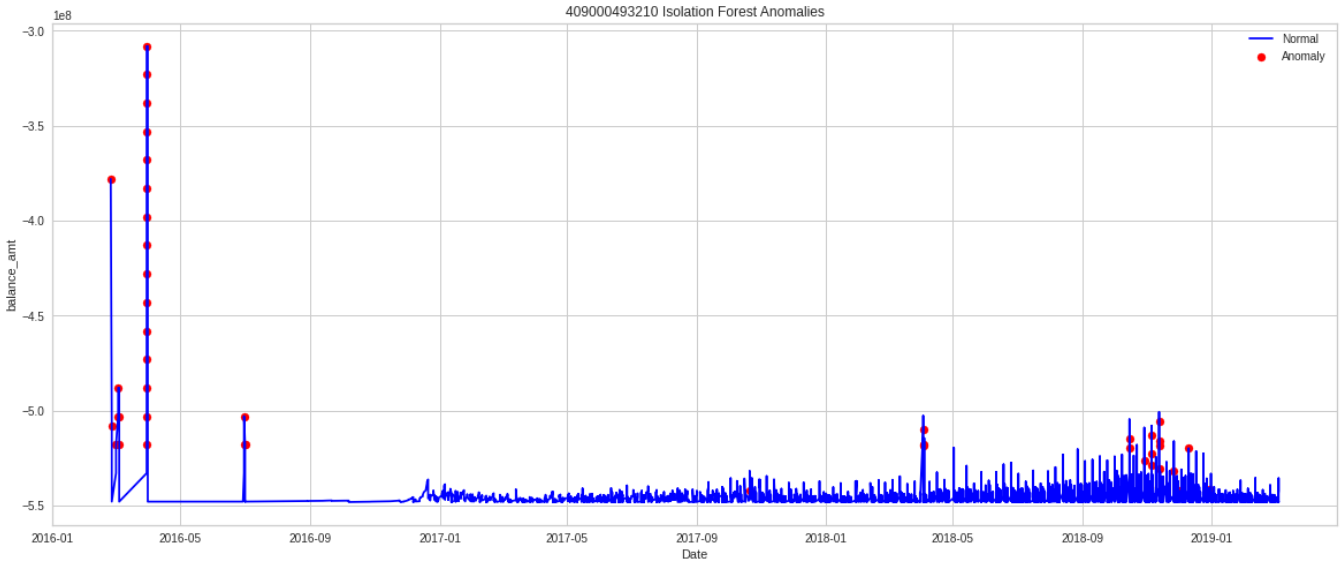
```
0    116155
1        46
Name: iso_6, dtype: int64
```

```
labels = acc6_iso_scaled.anomaly_iso
colors = {0:'blue', 1:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc6_iso_scaled.iloc[:,3], acc6_iso_scaled.iloc[:,4], acc6_iso_scal
ax.set_title(f'ISOLATION FOREST (account_no = {accounts[5]}, outliers_fraction
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
df = acc6_iso.copy()
a= df.loc[df['anomaly_iso']==1, ['date', 'balance_amt']]
plt.figure(figsize=(20,8))
plt.plot(df['date'], df['balance_amt'], color='blue', label='Normal')
plt.scatter(a['date'], a['balance_amt'], color='red', label='Anomaly')
plt.title(f'{accounts[4]} Isolation Forest Anomalies')
plt.xlabel('Date')
plt.ylabel('balance_amt')
plt.legend()
plt.show()
```



(VII) Isolation Forest account_no: 409000611074

```
acc7_iso = acc7.copy()
scaler = StandardScaler()
acc7_iso_scaled = pd.DataFrame(scaler.fit_transform(acc7_iso[acc7.columns[2:]]))
acc7_iso_scaled.set_index(acc7_iso.index, drop=True, inplace=True)
acc7_iso_scaled.head(3)
```

	day_diff	weekend_date	weekend_value_date	withdrawal_amt	deposit_amt	l
0	0.0	-0.269481	-0.269481	-0.687913	3.664767	
1	0.0	-0.269481	-0.269481	-0.687913	3.664767	
2	0.0	-0.269481	-0.269481	-0.687913	1.550196	

```
outliers_fraction = .01
model = IsolationForest(contamination=outliers_fraction)
model.fit(acc7_iso_scaled)
```

```
IsolationForest(behaviour='deprecated', bootstrap=False, contamination=0.01
                max_features=1.0, max_samples='auto', n_estimators=100,
                n_jobs=None, random_state=None, verbose=0, warm_start=False
```

```
acc7_iso_scaled['anomaly_iso'] = pd.Series(model.predict(acc7_iso_scaled)).app
acc7_iso['anomaly_iso'] = acc7_iso_scaled['anomaly_iso']
acc7_iso_scaled['anomaly_iso'].value_counts()
```

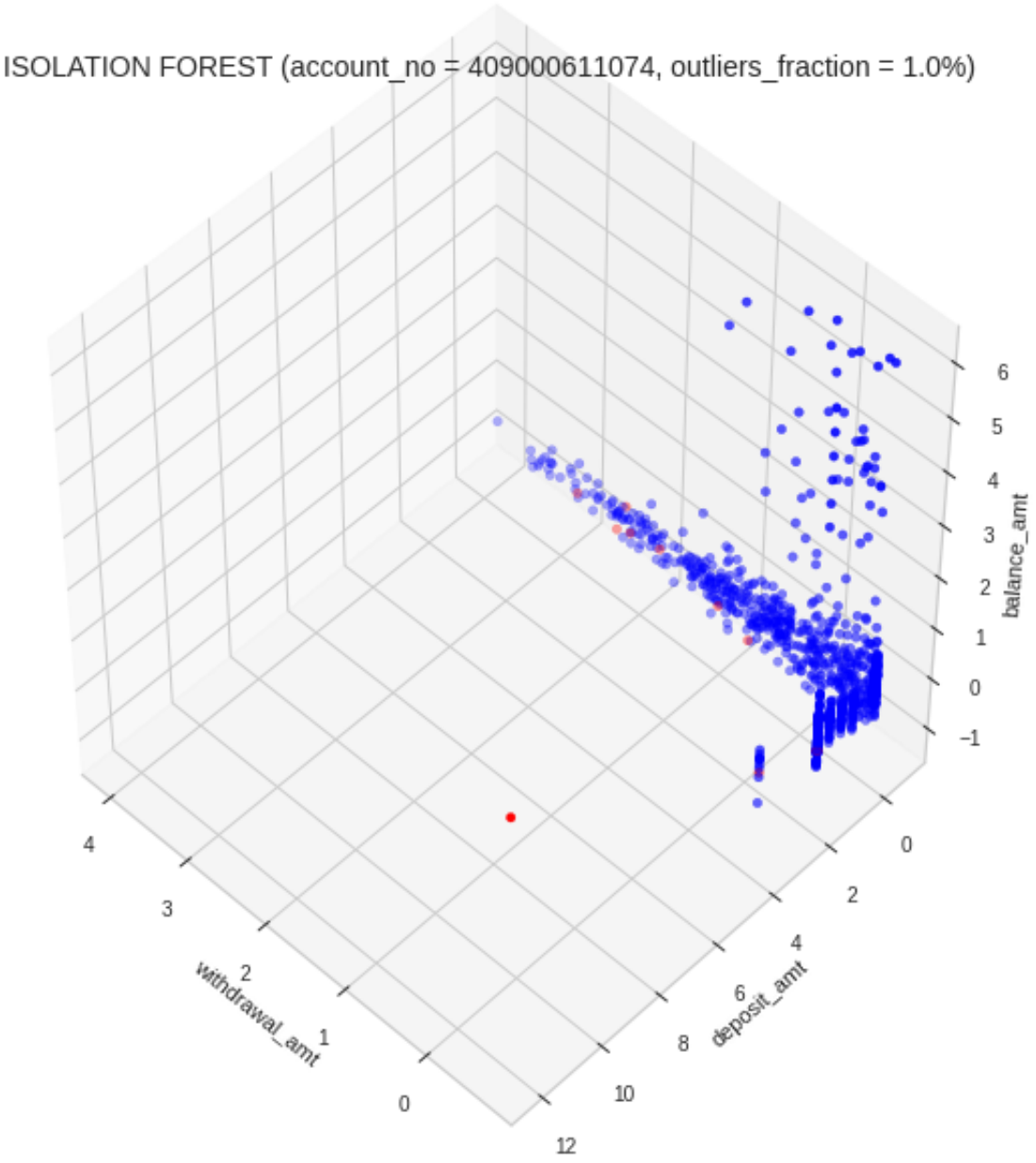
```
0    1082
1      11
Name: anomaly_iso, dtype: int64
```

```
bank_main['iso_7'] = 0
bank_main.loc[acc7_iso_scaled.index,'iso_7'] = acc7_iso_scaled['anomaly_iso']
bank_main['iso_7'].value_counts()
```

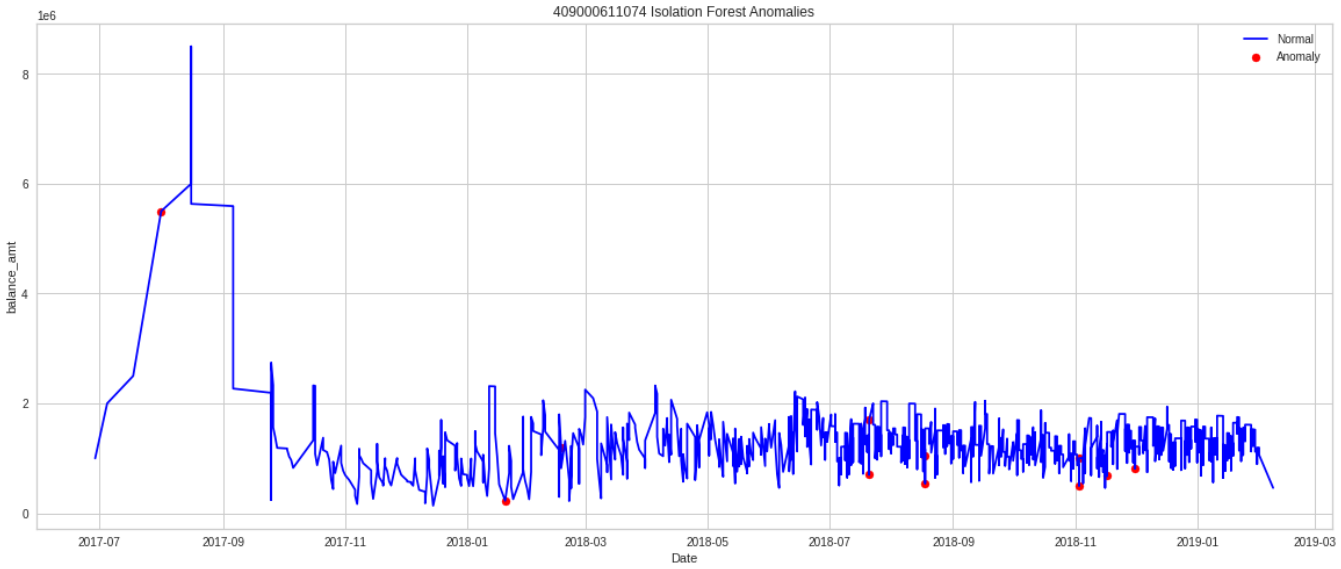
```
0    116190
1        11
Name: iso_7, dtype: int64
```

```
labels = acc7_iso_scaled.anomaly_iso
colors = {0:'blue', 1:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc7_iso_scaled.iloc[:,3], acc7_iso_scaled.iloc[:,4], acc7_iso_scal
ax.set_title(f'ISOLATION FOREST (account_no = {accounts[6]}, outliers_fraction
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
df = acc7_iso.copy()
a= df.loc[df['anomaly_iso']==1, ['date', 'balance_amt']]
plt.figure(figsize=(20,8))
plt.plot(df['date'], df['balance_amt'], color='blue', label='Normal')
plt.scatter(a['date'], a['balance_amt'], color='red', label='Anomaly')
plt.title(f'{accounts[6]} Isolation Forest Anomalies')
plt.xlabel('Date')
plt.ylabel('balance_amt')
plt.legend()
plt.show()
```



(VIII) Isolation Forest account_no: 409000493201

```
acc8_iso = acc8.copy()
scaler = StandardScaler()
acc8_iso_scaled = pd.DataFrame(scaler.fit_transform(acc8_iso[acc8.columns[2:]]))
acc8_iso_scaled.set_index(acc8_iso.index, drop=True, inplace=True)
acc8_iso_scaled.head(3)
```

	day_diff	weekend_date	weekend_value_date	withdrawal_amt	deposit_amt
1093	0.0	-0.261873	-0.261873	-0.450731	3.00717
1094	0.0	-0.261873	-0.261873	-0.446770	-0.67472
1095	0.0	-0.261873	-0.261873	-0.449547	-0.67472

```
outliers_fraction = .01
model = IsolationForest(contamination=outliers_fraction)
model.fit(acc8_iso_scaled)
```

```
IsolationForest(behaviour='deprecated', bootstrap=False, contamination=0.01
                max_features=1.0, max_samples='auto', n_estimators=100,
                n_jobs=None, random_state=None, verbose=0, warm_start=False
```

```
acc8_iso_scaled['anomaly_iso'] = pd.Series(model.predict(acc8_iso_scaled)).app
acc8_iso['anomaly_iso'] = acc8_iso_scaled['anomaly_iso']
acc8_iso_scaled['anomaly_iso'].value_counts()
```

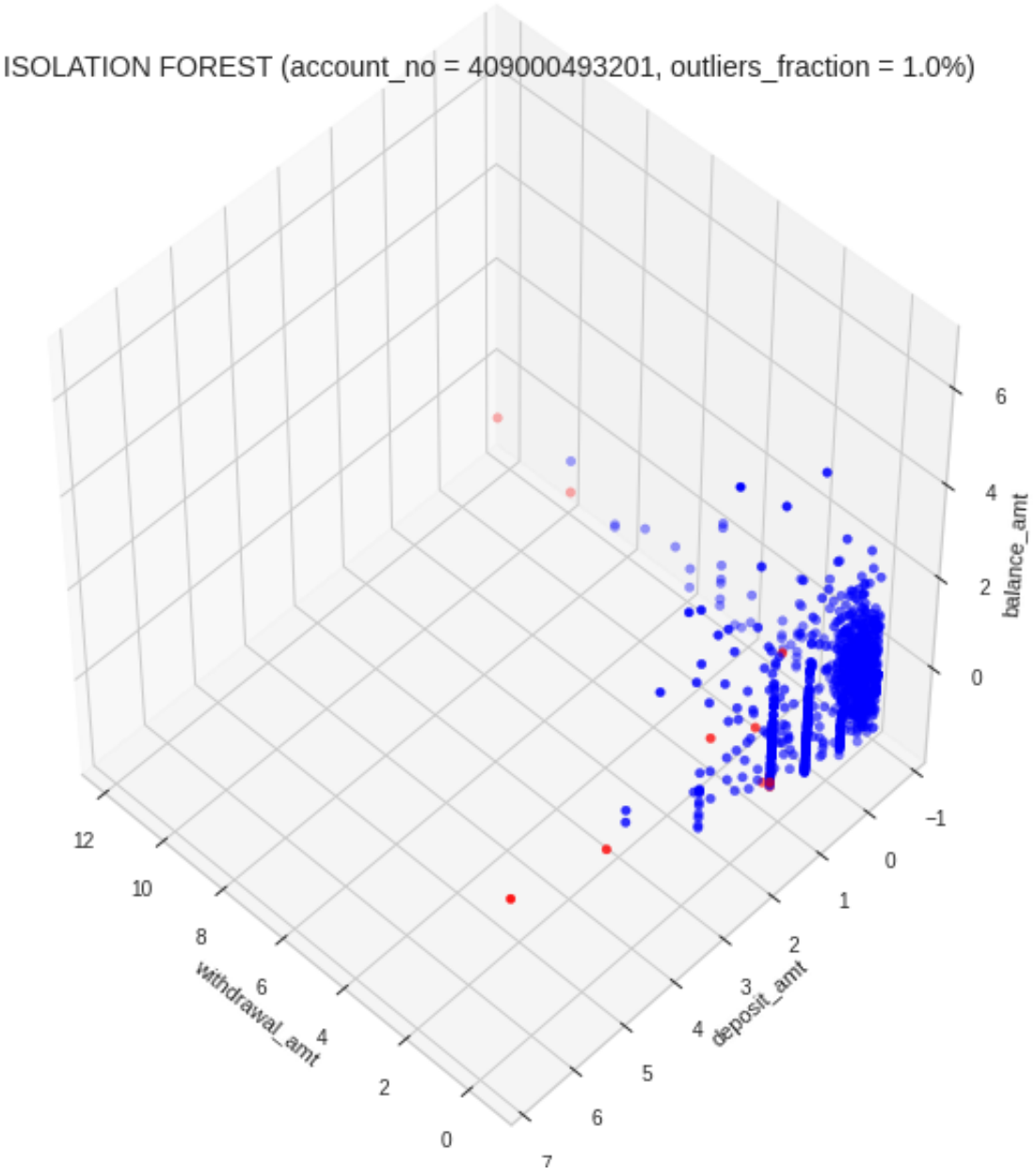
```
0    1033
1      11
Name: anomaly_iso, dtype: int64
```

```
bank_main['iso_8'] = 0
bank_main.loc[acc8_iso_scaled.index,'iso_8'] = acc8_iso_scaled['anomaly_iso']
bank_main['iso_8'].value_counts()
```

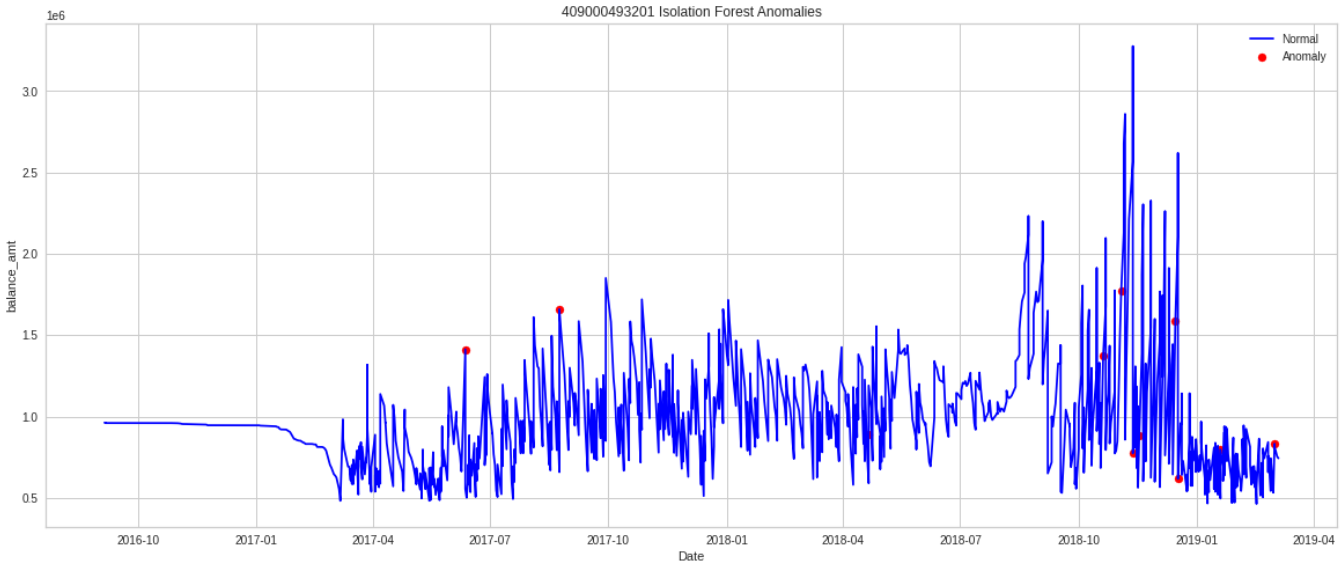
```
0    116190
1        11
Name: iso_8, dtype: int64
```

```
labels = acc8_iso_scaled.anomaly_iso
colors = {0:'blue', 1:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc8_iso_scaled.iloc[:,3], acc8_iso_scaled.iloc[:,4], acc8_iso_scal
ax.set_title(f'ISOLATION FOREST (account_no = {accounts[7]}, outliers_fraction
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
df = acc8_iso.copy()
a= df.loc[df['anomaly_iso']==1, ['date', 'balance_amt']]
plt.figure(figsize=(20,8))
plt.plot(df['date'], df['balance_amt'], color='blue', label='Normal')
plt.scatter(a['date'], a['balance_amt'], color='red', label='Anomaly')
plt.title(f'{accounts[7]} Isolation Forest Anomalies')
plt.xlabel('Date')
plt.ylabel('balance_amt')
plt.legend()
plt.show()
```



(IX) Isolation Forest account_no: 409000425051

```
acc9_iso = acc9.copy()
scaler = StandardScaler()
acc9_iso_scaled = pd.DataFrame(scaler.fit_transform(acc9_iso[acc9.columns[2:]]))
acc9_iso_scaled.set_index(acc9_iso.index, drop=True, inplace=True)
acc9_iso_scaled.head(3)
```

	day_diff	weekend_date	weekend_value_date	withdrawal_amt	deposit_amt
2137	0.0	-0.429695	-0.429695	-0.038344	-0.02322
2138	0.0	-0.429695	-0.429695	-0.038344	-0.05979
2139	0.0	-0.429695	-0.429695	-0.038344	-0.02322

```
outliers_fraction = .01
model = IsolationForest(contamination=outliers_fraction)
model.fit(acc9_iso_scaled)
```

```
IsolationForest(behaviour='deprecated', bootstrap=False, contamination=0.01
                max_features=1.0, max_samples='auto', n_estimators=100,
                n_jobs=None, random_state=None, verbose=0, warm_start=False
```

```
acc9_iso_scaled['anomaly_iso'] = pd.Series(model.predict(acc9_iso_scaled)).app
acc9_iso['anomaly_iso'] = acc9_iso_scaled['anomaly_iso']
acc9_iso_scaled['anomaly_iso'].value_counts()
```

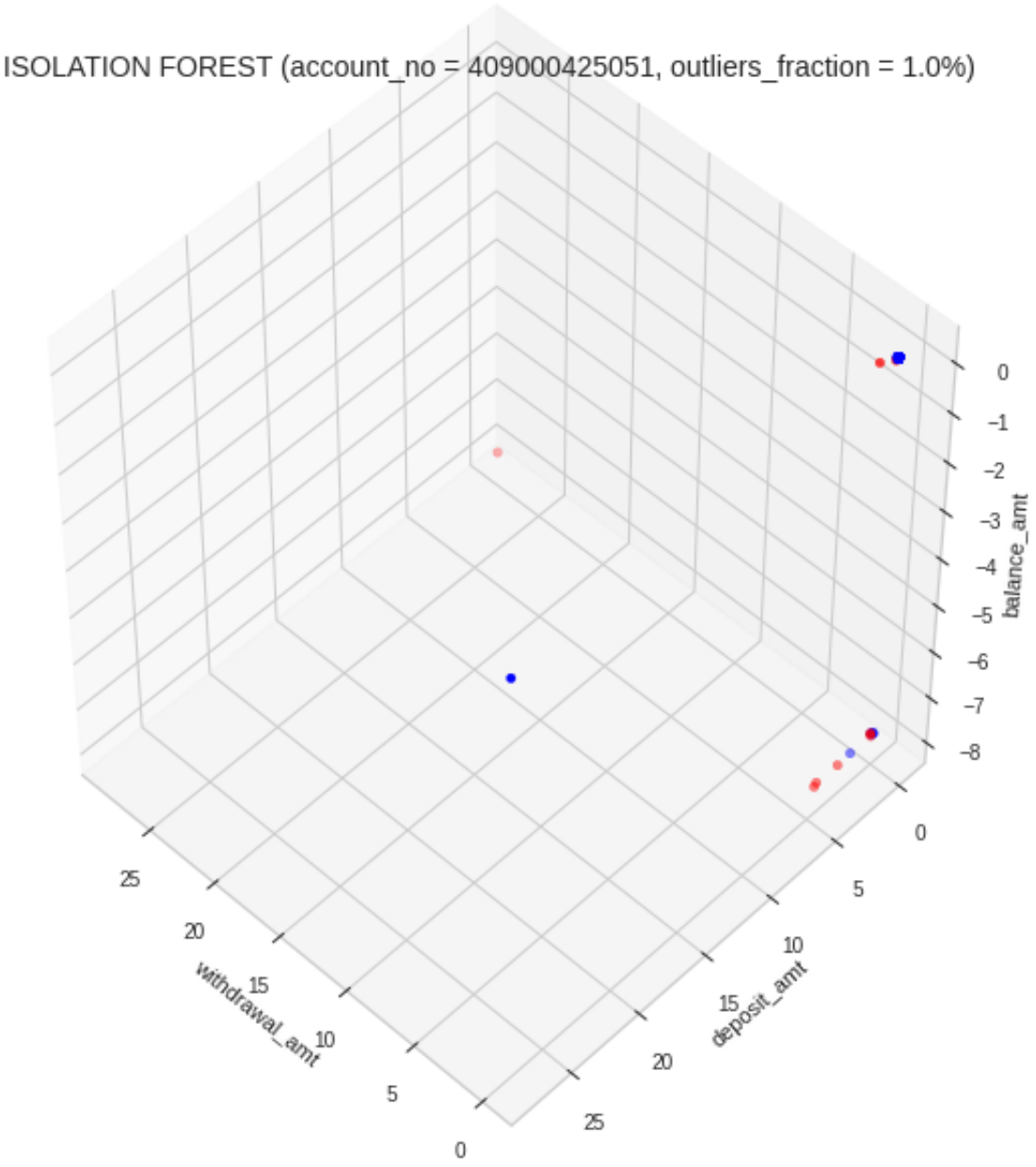
```
0    793
1      9
Name: anomaly_iso, dtype: int64
```

```
bank_main['iso_9'] = 0
bank_main.loc[acc9_iso_scaled.index,'iso_9'] = acc9_iso_scaled['anomaly_iso']
bank_main['iso_9'].value_counts()
```

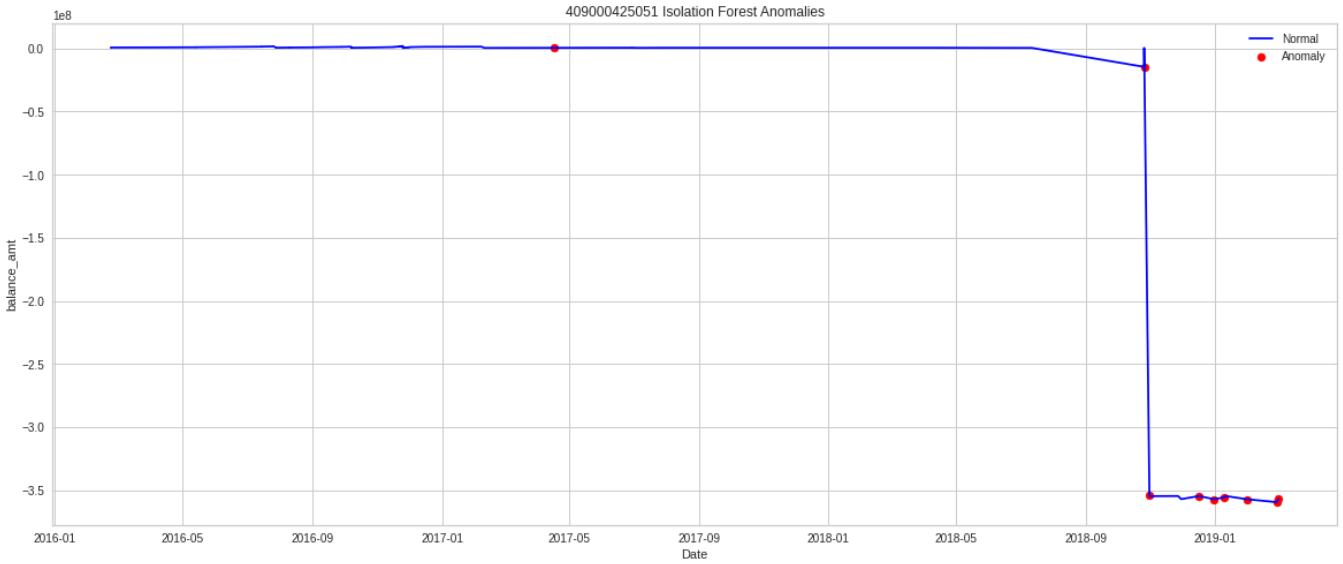
```
0    116192
1         9
Name: iso_9, dtype: int64
```

```
labels = acc9_iso_scaled.anomaly_iso
colors = {0:'blue', 1:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc9_iso_scaled.iloc[:,3], acc9_iso_scaled.iloc[:,4], acc9_iso_scal
ax.set_title(f'ISOLATION FOREST (account_no = {accounts[8]}, outliers_fraction
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
df = acc9_iso.copy()
a= df.loc[df['anomaly_iso']==1, ['date', 'balance_amt']]
plt.figure(figsize=(20,8))
plt.plot(df['date'], df['balance_amt'], color='blue', label='Normal')
plt.scatter(a['date'], a['balance_amt'], color='red', label='Anomaly')
plt.title(f'{accounts[8]} Isolation Forest Anomalies')
plt.xlabel('Date')
plt.ylabel('balance_amt')
plt.legend()
plt.show()
```



(X) Isolation Forest account_no: 409000405747

```
acc10_iso = acc10.copy()
scaler = StandardScaler()
acc10_iso_scaled = pd.DataFrame(scaler.fit_transform(acc10_iso[acc10.columns[2:
acc10_iso_scaled.set_index(acc10_iso.index, drop=True, inplace=True)
acc10_iso_scaled.head(3)
```

	day_diff	weekend_date	weekend_value_date	withdrawal_amt	deposit_am
2939	0.0	2.318405	2.318405	5.917619	-0.16033
2940	0.0	2.318405	2.318405	0.795991	-0.16033
2941	0.0	2.318405	2.318405	-0.296882	-0.16033

```
outliers_fraction = .1
model = IsolationForest(contamination=outliers_fraction)
model.fit(acc10_iso_scaled)
```

```
IsolationForest(behaviour='deprecated', bootstrap=False, contamination=0.1,
                max_features=1.0, max_samples='auto', n_estimators=100,
                n_jobs=None, random_state=None, verbose=0, warm_start=False
```

```
acc10_iso_scaled['anomaly_iso'] = pd.Series(model.predict(acc10_iso_scaled)).a
acc10_iso['anomaly_iso'] = acc10_iso_scaled['anomaly_iso']
acc10_iso_scaled['anomaly_iso'].value_counts()
```

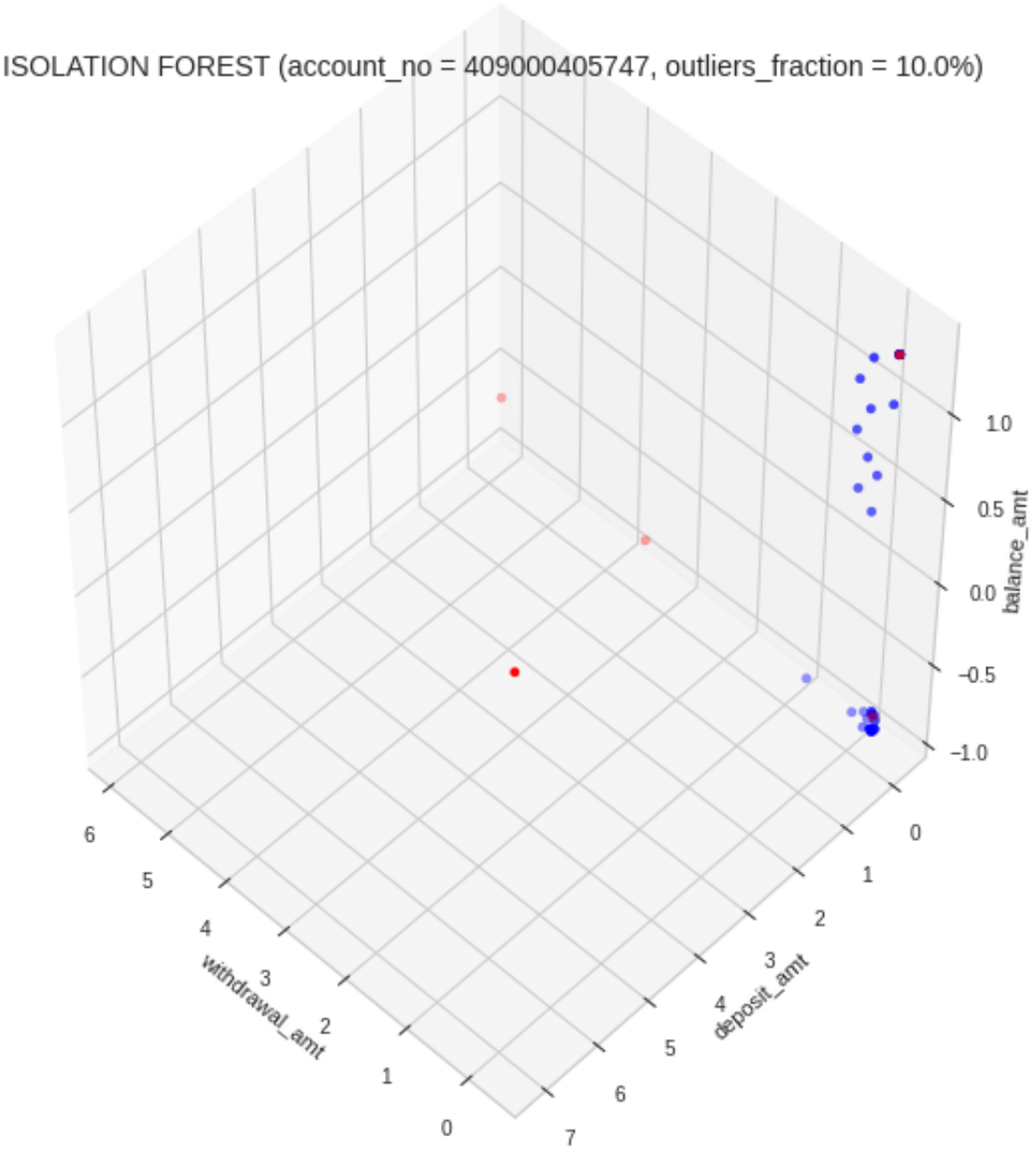
```
0    46
1     5
Name: anomaly_iso, dtype: int64
```

```
bank_main['iso_10'] = 0
bank_main.loc[acc10_iso_scaled.index,'iso_10'] = acc10_iso_scaled['anomaly_iso
bank_main['iso_10'].value_counts()
```

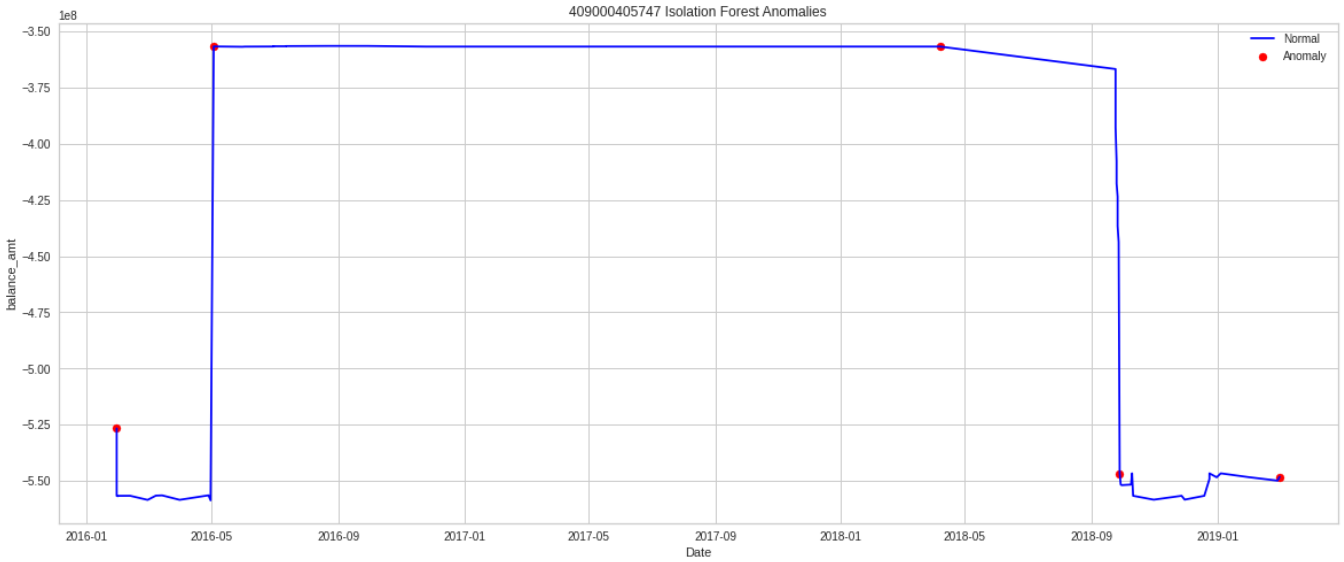
```
0    116196
1         5
Name: iso_10, dtype: int64
```

```
labels = acc10_iso_scaled.anomaly_iso
colors = {0:'blue', 1:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc10_iso_scaled.iloc[:,3], acc10_iso_scaled.iloc[:,4], acc10_iso_s
ax.set_title(f'ISOLATION FOREST (account_no = {accounts[9]}, outliers_fraction
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
df = acc10_iso.copy()
a= df.loc[df['anomaly_iso']==1, ['date', 'balance_amt']]
plt.figure(figsize=(20,8))
plt.plot(df['date'], df['balance_amt'], color='blue', label='Normal')
plt.scatter(a['date'], a['balance_amt'], color='red', label='Anomaly')
plt.title(f'{accounts[9]} Isolation Forest Anomalies')
plt.xlabel('Date')
plt.ylabel('balance_amt')
plt.legend()
plt.show()
```




```
bank_main['accounts_isolation_forest'] = bank_main.iso_1 + bank_main.iso_2 + ba

#bank_main.drop(columns=['iso_1', 'iso_2', 'iso_3', 'iso_4', 'iso_5', 'iso_6',
```

```
bank_main['accounts_isolation_forest'].value_counts()
```

```
0    115433
1       768
Name: accounts_isolation_forest, dtype: int64
```

ii. OneClassSVM Anomaly Detection

(I) OneClassSVM account_no: 1196428

```
acc1_svm = acc1.copy()
scaler = StandardScaler()
acc1_svm_scaled = pd.DataFrame(scaler.fit_transform(acc1_svm[acc1.columns[2:]]))
acc1_svm_scaled.set_index(acc1_svm.index, drop=True, inplace=True)
acc1_svm_scaled.head(3)
```

	day_diff	weekend_date	weekend_value_date	withdrawal_amt	deposit_ar
37582	-0.009703	-0.327498	-0.327574	-0.363895	-0.0352
37583	-0.009703	-0.327498	-0.327574	-0.363895	-0.1051
37584	-0.009703	-0.327498	-0.327574	-0.363895	-0.2422

```
outliers_fraction = .005
model = OneClassSVM(nu=outliers_fraction, kernel='rbf', gamma=.01)
model.fit(acc1_svm_scaled)
```

```
OneClassSVM(cache_size=200, coef0=0.0, degree=3, gamma=0.01, kernel='rbf',
            max_iter=-1, nu=0.005, shrinking=True, tol=0.001, verbose=False
```

```
acc1_svm_scaled['anomaly_svm'] = pd.Series(model.predict(acc1_svm_scaled)).app
acc1_svm['anomaly_svm'] = acc1_svm_scaled['anomaly_svm']
acc1_svm_scaled['anomaly_svm'].value_counts()
```

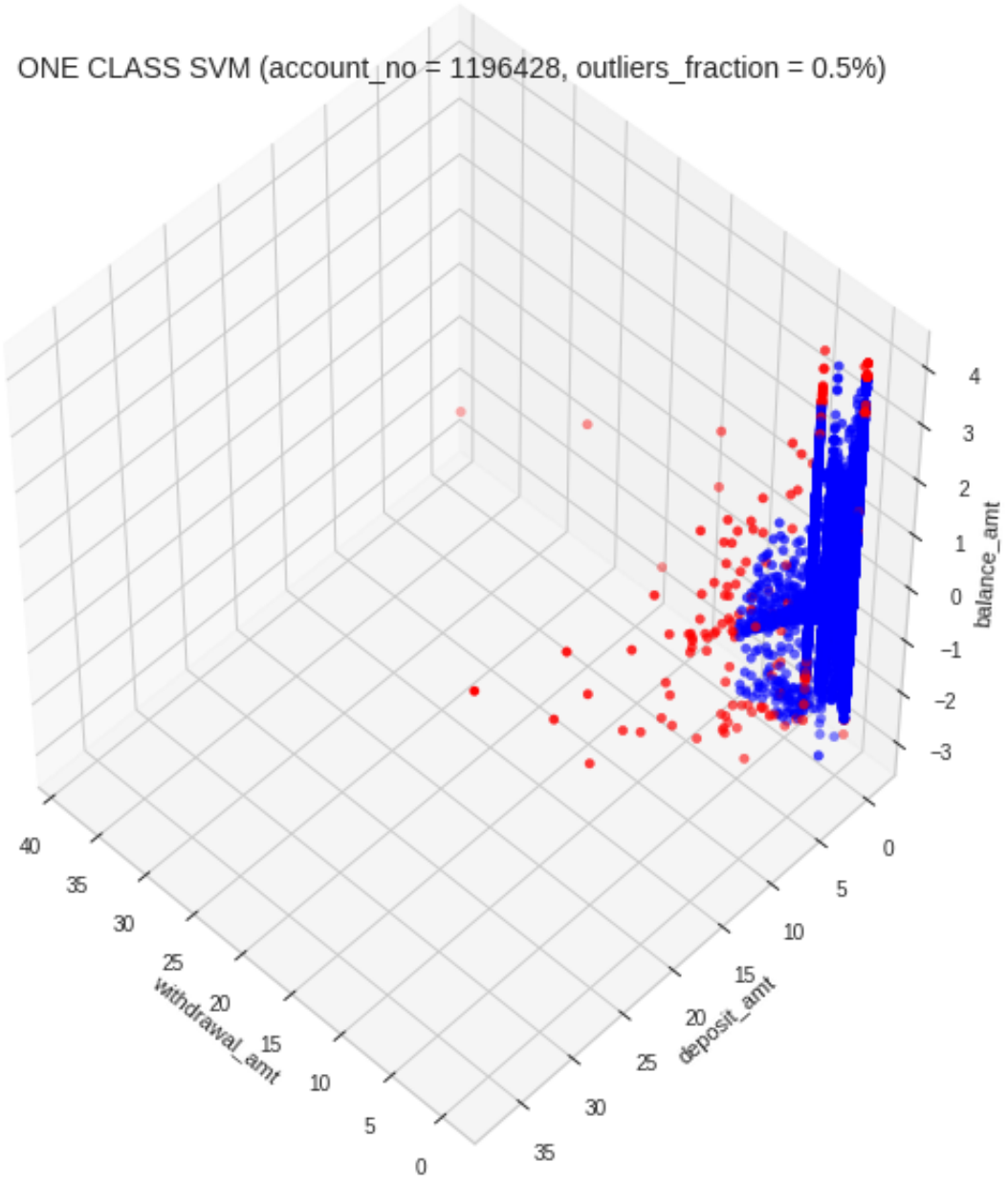
```
0    48533
1      246
Name: anomaly_svm, dtype: int64
```

```
bank_main['svm_1'] = 0
bank_main.loc[acc1_svm_scaled.index,'svm_1'] = acc1_svm_scaled['anomaly_svm']
bank_main['svm_1'].value_counts()
```

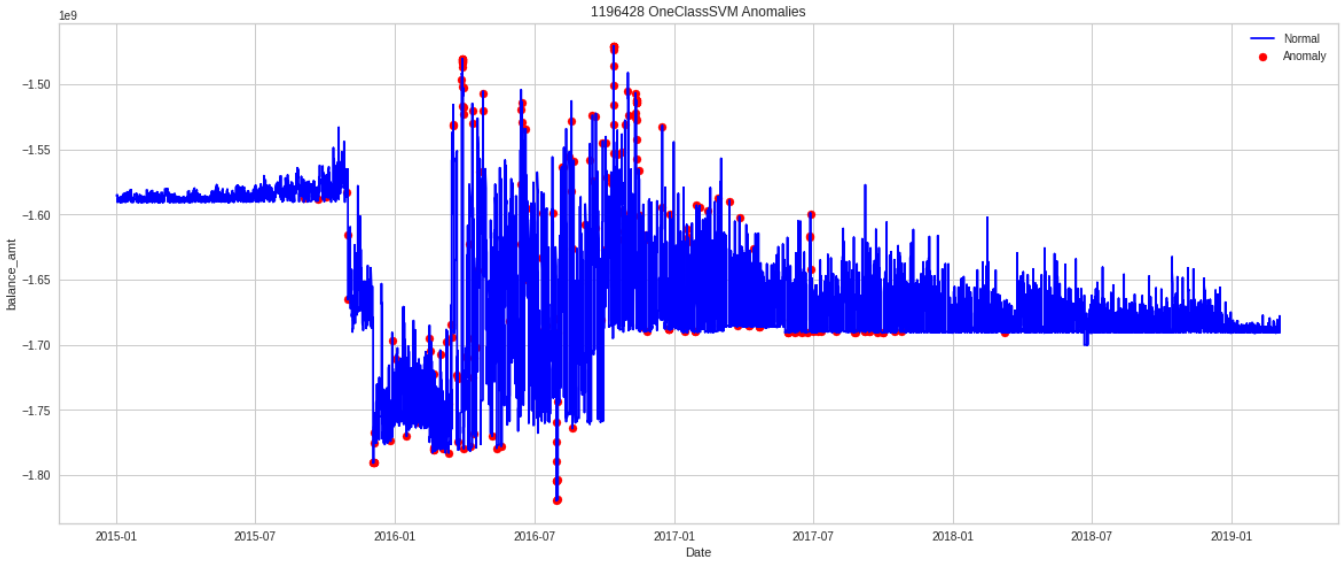
```
0    115955
1       246
Name: svm_1, dtype: int64
```

```
labels = acc1_svm_scaled.anomaly_svm
colors = {0:'blue', 1:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc1_svm_scaled.iloc[:,3], acc1_svm_scaled.iloc[:,4], acc1_svm_scal
ax.set_title(f'ONE CLASS SVM (account_no = {accounts[0]}, outliers_fraction = 
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
df = acc1_svm.copy()
a= df.loc[df['anomaly_svm']==1, ['date', 'balance_amt']]
plt.figure(figsize=(20,8))
plt.plot(df['date'], df['balance_amt'], color='blue', label='Normal')
plt.scatter(a['date'], a['balance_amt'], color='red', label='Anomaly')
plt.title(f'{accounts[0]} OneClassSVM Anomalies')
plt.xlabel('Date')
plt.ylabel('balance_amt')
plt.legend()
plt.show()
```



(II) OneClassSVM account_no: 409000362497

```
acc2_svm = acc2.copy()
scaler = StandardScaler()
acc2_svm_scaled = pd.DataFrame(scaler.fit_transform(acc2_svm[acc2.columns[2:]]))
acc2_svm_scaled.set_index(acc2_svm.index, drop=True, inplace=True)
acc2_svm_scaled.head(3)
```

	day_diff	weekend_date	weekend_value_date	withdrawal_amt	deposit_ar
86361	-0.020357	-0.286669	-0.286463	-0.297246	1.00303
86362	-0.020357	-0.286669	-0.286463	-0.297246	1.00303
86363	-0.020357	-0.286669	-0.286463	-0.297246	1.00303

```
outliers_fraction = .005
model = OneClassSVM(nu=outliers_fraction, kernel='rbf', gamma=.01)
model.fit(acc2_svm_scaled)
```

```
OneClassSVM(cache_size=200, coef0=0.0, degree=3, gamma=0.01, kernel='rbf',
            max_iter=-1, nu=0.005, shrinking=True, tol=0.001, verbose=False
```

```
acc2_svm_scaled['anomaly_svm'] = pd.Series(model.predict(acc2_svm_scaled)).app
acc2_svm['anomaly_svm'] = acc2_svm_scaled['anomaly_svm']
acc2_svm_scaled['anomaly_svm'].value_counts()
```

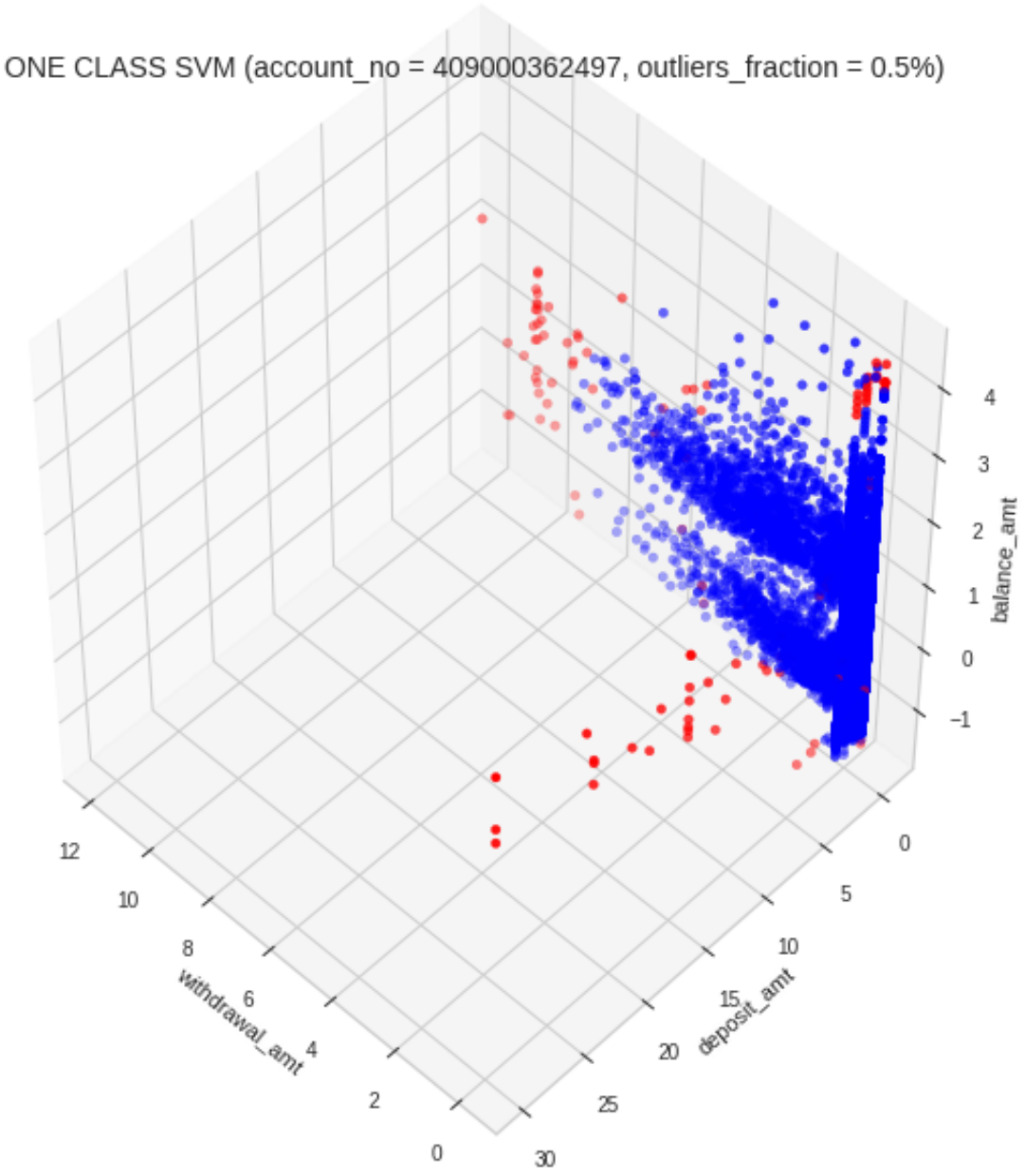
```
0    29692
1      148
Name: anomaly_svm, dtype: int64
```

```
bank_main['svm_2'] = 0
bank_main.loc[acc2_svm_scaled.index,'svm_2'] = acc2_svm_scaled['anomaly_svm']
bank_main['svm_2'].value_counts()
```

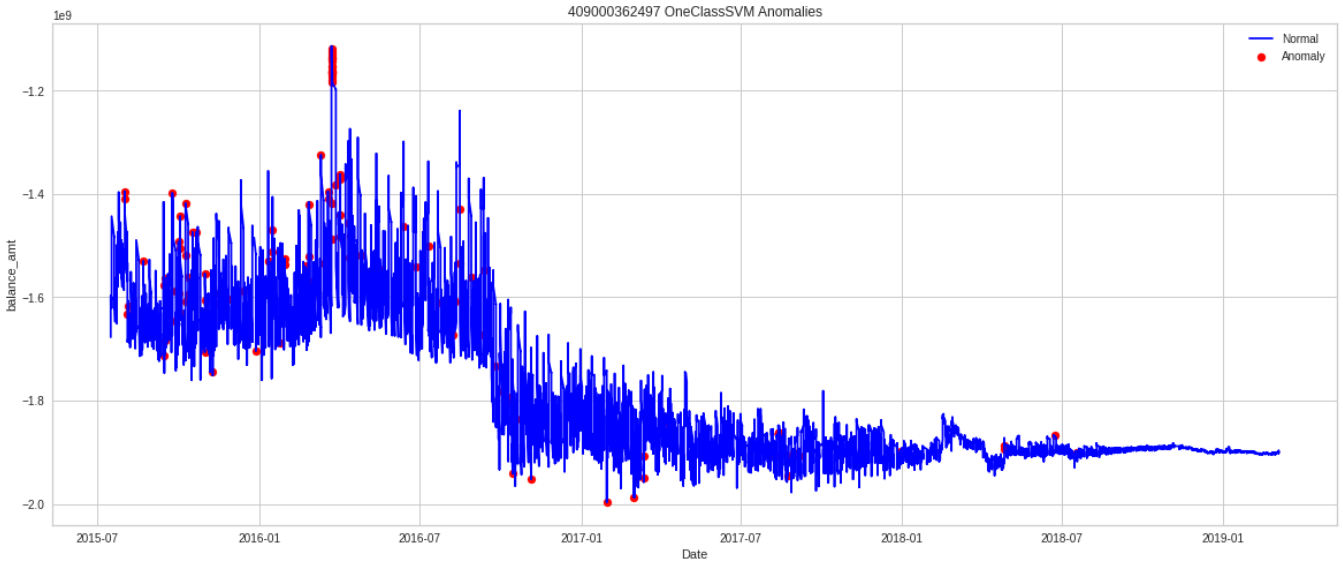
```
0    116053
1       148
Name: svm_2, dtype: int64
```

```
labels = acc2_svm_scaled.anomaly_svm
colors = {0:'blue', 1:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc2_svm_scaled.iloc[:,3], acc2_svm_scaled.iloc[:,4], acc2_svm_scal
ax.set_title(f'ONE CLASS SVM (account_no = {accounts[1]}, outliers_fraction = 
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
df = acc2_svm.copy()
a= df.loc[df['anomaly_svm']==1, ['date', 'balance_amt']]
plt.figure(figsize=(20,8))
plt.plot(df['date'], df['balance_amt'], color='blue', label='Normal')
plt.scatter(a['date'], a['balance_amt'], color='red', label='Anomaly')
plt.title(f'{accounts[1]} OneClassSVM Anomalies')
plt.xlabel('Date')
plt.ylabel('balance_amt')
plt.legend()
plt.show()
```



(III) OneClassSVM account_no: 409000438620

```
acc3_svm = acc3.copy()
scaler = StandardScaler()
acc3_svm_scaled = pd.DataFrame(scaler.fit_transform(acc3_svm[acc3.columns[2:]]))
acc3_svm_scaled.set_index(acc3_svm.index, drop=True, inplace=True)
acc3_svm_scaled.head(3)
```

	day_diff	weekend_date	weekend_value_date	withdrawal_amt	deposit_ar
13592	0.0	-0.310493	-0.310493	-0.199596	68.5563
13593	0.0	-0.310493	-0.310493	15.416558	-0.1612
13594	0.0	-0.310493	-0.310493	-0.199596	1.7307

```
outliers_fraction = .005
model = OneClassSVM(nu=outliers_fraction, kernel='rbf', gamma=.01)
model.fit(acc3_svm_scaled)
```

```
OneClassSVM(cache_size=200, coef0=0.0, degree=3, gamma=0.01, kernel='rbf',
            max_iter=-1, nu=0.005, shrinking=True, tol=0.001, verbose=False
```

```
acc3_svm_scaled['anomaly_svm'] = pd.Series(model.predict(acc3_svm_scaled)).app
acc3_svm['anomaly_svm'] = acc3_svm_scaled['anomaly_svm']
acc3_svm_scaled['anomaly_svm'].value_counts()
```

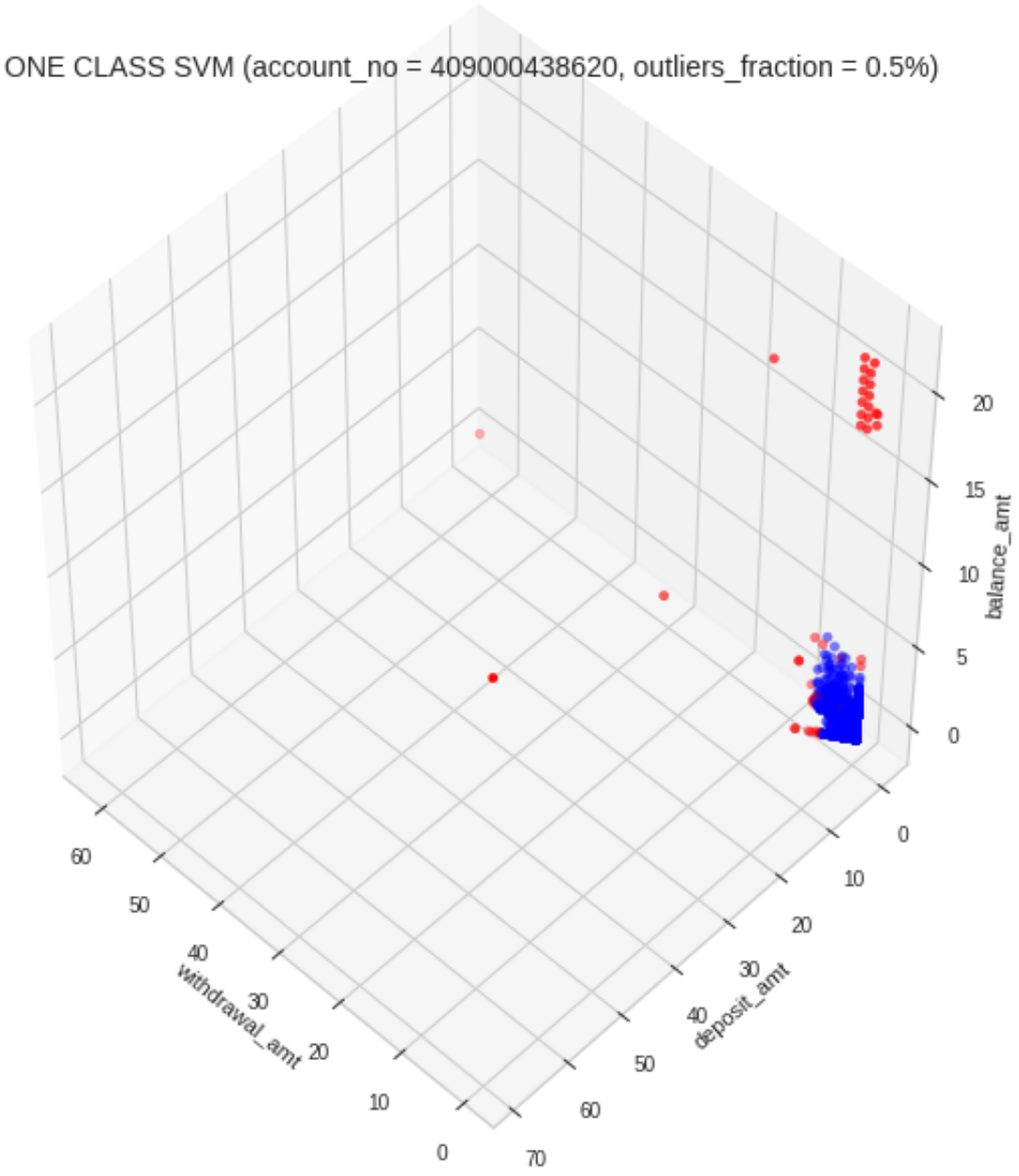
```
0    13385
1       69
Name: anomaly_svm, dtype: int64
```

```
bank_main['svm_3'] = 0
bank_main.loc[acc3_svm_scaled.index,'svm_3'] = acc3_svm_scaled['anomaly_svm']
bank_main['svm_3'].value_counts()
```

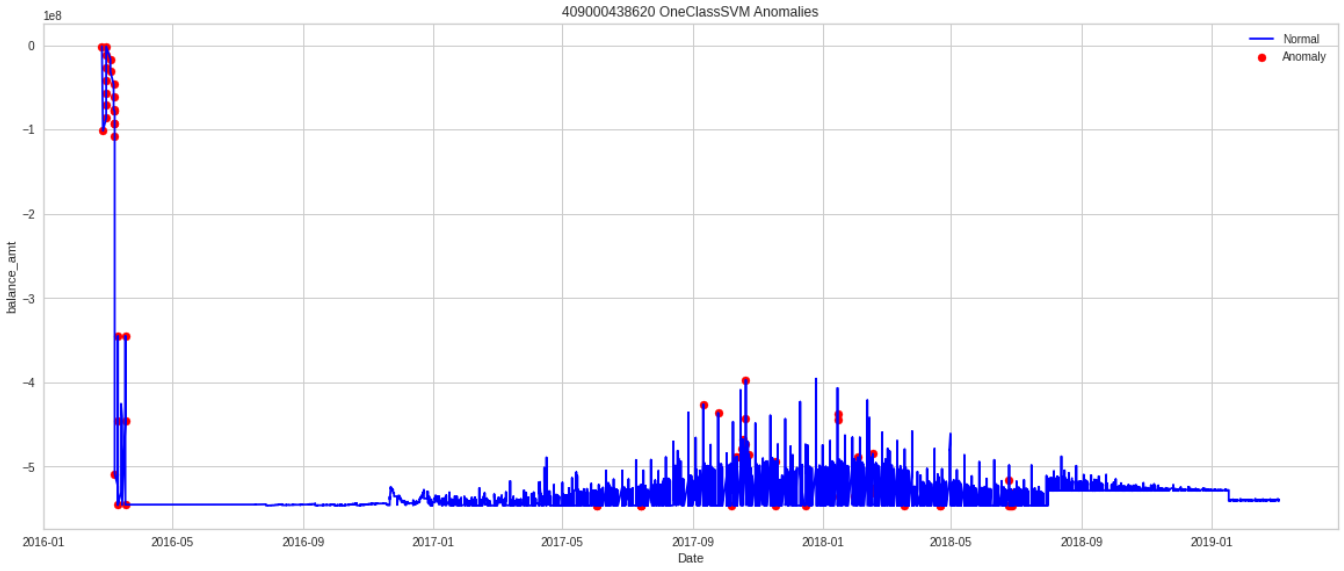
```
0    116132
1        69
Name: svm_3, dtype: int64
```

```
labels = acc3_svm_scaled.anomaly_svm
colors = {0:'blue', 1:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc3_svm_scaled.iloc[:,3], acc3_svm_scaled.iloc[:,4], acc3_svm_scal
ax.set_title(f'ONE CLASS SVM (account_no = {accounts[2]}, outliers_fraction = 
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
df = acc3_svm.copy()
a= df.loc[df['anomaly_svm']==1, ['date', 'balance_amt']]
plt.figure(figsize=(20,8))
plt.plot(df['date'], df['balance_amt'], color='blue', label='Normal')
plt.scatter(a['date'], a['balance_amt'], color='red', label='Anomaly')
plt.title(f'{accounts[2]} OneClassSVM Anomalies')
plt.xlabel('Date')
plt.ylabel('balance_amt')
plt.legend()
plt.show()
```



(IV) OneClassSVM account_no: 1196711

```
acc4_svm = acc4.copy()
scaler = StandardScaler()
acc4_svm_scaled = pd.DataFrame(scaler.fit_transform(acc4_svm[acc4.columns[2:]]))
acc4_svm_scaled.set_index(acc4_svm.index, drop=True, inplace=True)
acc4_svm_scaled.head(3)
```

	day_diff	weekend_date	weekend_value_date	withdrawal_amt	deposit_ar
27046	-0.06111	-0.308943	-0.309496	-0.415321	-0.4182(
27047	-0.06111	-0.308943	-0.309496	-0.415321	-0.4184(
27048	-0.06111	-0.308943	-0.309496	-0.415321	-0.4183(

```
outliers_fraction = .005
model = OneClassSVM(nu=outliers_fraction, kernel='rbf', gamma=.01)
model.fit(acc4_svm_scaled)
```

```
OneClassSVM(cache_size=200, coef0=0.0, degree=3, gamma=0.01, kernel='rbf',
            max_iter=-1, nu=0.005, shrinking=True, tol=0.001, verbose=False
```

```
acc4_svm_scaled['anomaly_svm'] = pd.Series(model.predict(acc4_svm_scaled)).app
acc4_svm['anomaly_svm'] = acc4_svm_scaled['anomaly_svm']
acc4_svm_scaled['anomaly_svm'].value_counts()
```

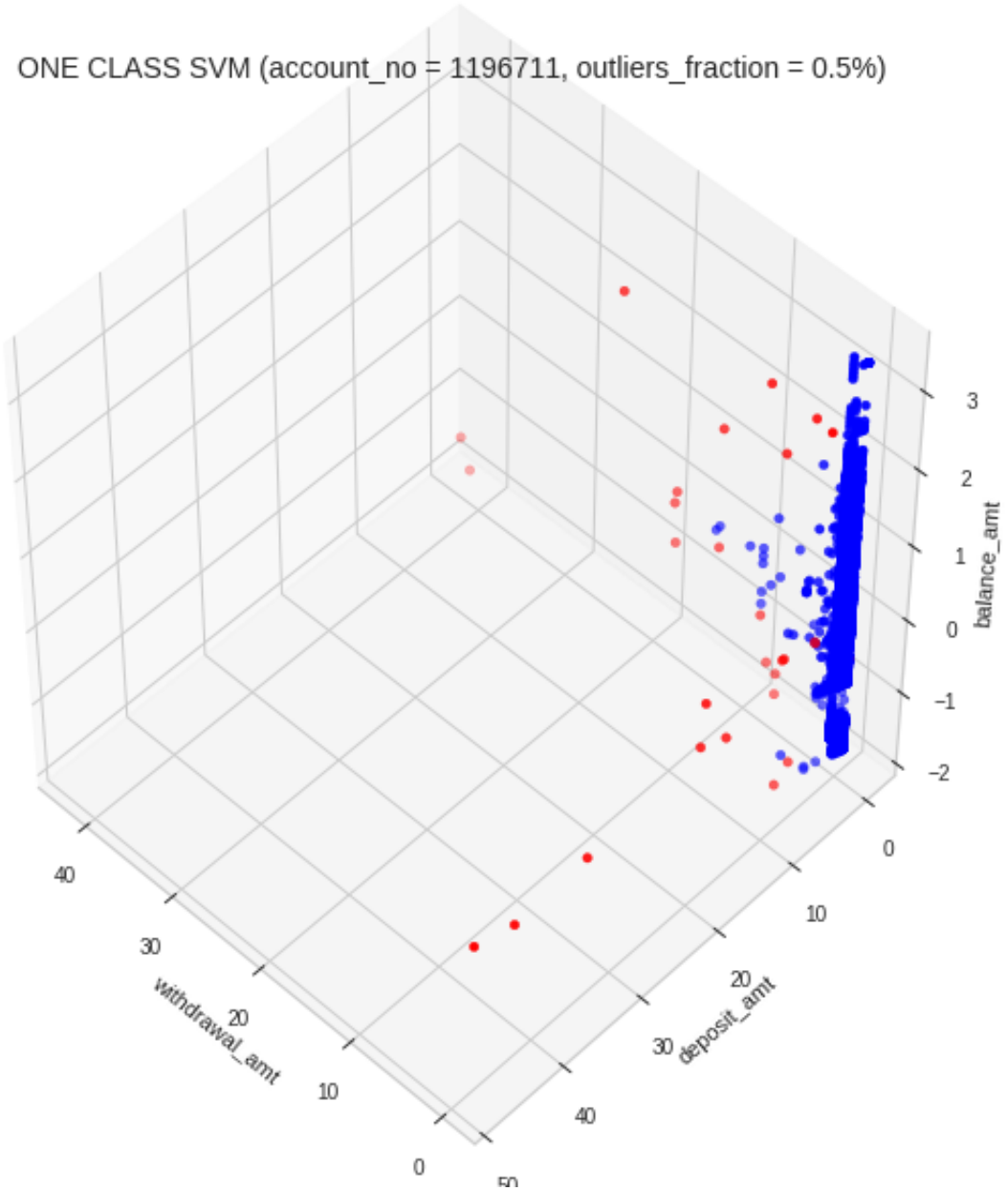
```
0    10496
1       40
Name: anomaly_svm, dtype: int64
```

```
bank_main['svm_4'] = 0
bank_main.loc[acc4_svm_scaled.index,'svm_4'] = acc4_svm_scaled['anomaly_svm']
bank_main['svm_4'].value_counts()
```

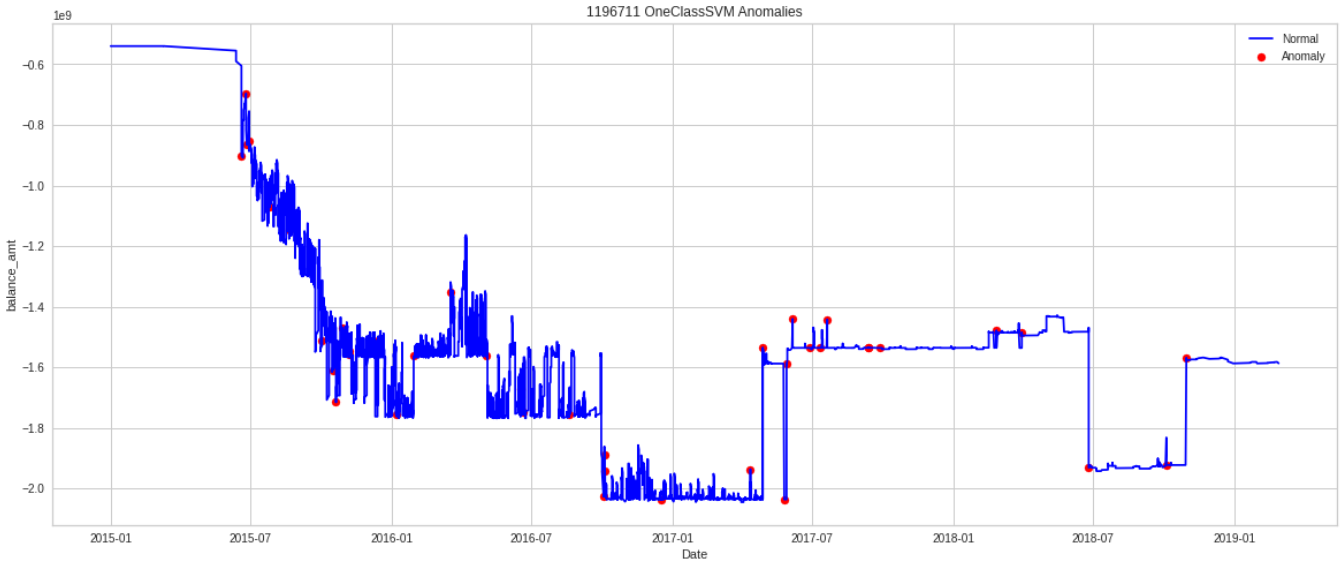
```
0    116161
1        40
Name: svm_4, dtype: int64
```

```
labels = acc4_svm_scaled.anomaly_svm
colors = {0:'blue', 1:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc4_svm_scaled.iloc[:,3], acc4_svm_scaled.iloc[:,4], acc4_svm_scal
ax.set_title(f'ONE CLASS SVM (account_no = {accounts[3]}, outliers_fraction = 
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
df = acc4_svm.copy()
a= df.loc[df['anomaly_svm']==1, ['date', 'balance_amt']]
plt.figure(figsize=(20,8))
plt.plot(df['date'], df['balance_amt'], color='blue', label='Normal')
plt.scatter(a['date'], a['balance_amt'], color='red', label='Anomaly')
plt.title(f'{accounts[3]} OneClassSVM Anomalies')
plt.xlabel('Date')
plt.ylabel('balance_amt')
plt.legend()
plt.show()
```



(V) OneClassSVM account_no: 409000493210

```
acc5_svm = acc5.copy()
scaler = StandardScaler()
acc5_svm_scaled = pd.DataFrame(scaler.fit_transform(acc5_svm[acc5.columns[2:]]))
acc5_svm_scaled.set_index(acc5_svm.index, drop=True, inplace=True)
acc5_svm_scaled.head(3)
```

	day_diff	weekend_date	weekend_value_date	withdrawal_amt	deposit_am
7578	0.0	-0.249713	-0.249713	-0.042609	1.20359
7579	0.0	-0.249713	-0.249713	-0.042227	-0.04235
7580	0.0	-0.249713	-0.249713	-0.042555	-0.04235

```
outliers_fraction = .005
model = OneClassSVM(nu=outliers_fraction, kernel='rbf', gamma=.01)
model.fit(acc5_svm_scaled)
```

```
OneClassSVM(cache_size=200, coef0=0.0, degree=3, gamma=0.01, kernel='rbf',
            max_iter=-1, nu=0.005, shrinking=True, tol=0.001, verbose=False
```

```
acc5_svm_scaled['anomaly_svm'] = pd.Series(model.predict(acc5_svm_scaled)).app
acc5_svm['anomaly_svm'] = acc5_svm_scaled['anomaly_svm']
acc5_svm_scaled['anomaly_svm'].value_counts()
```

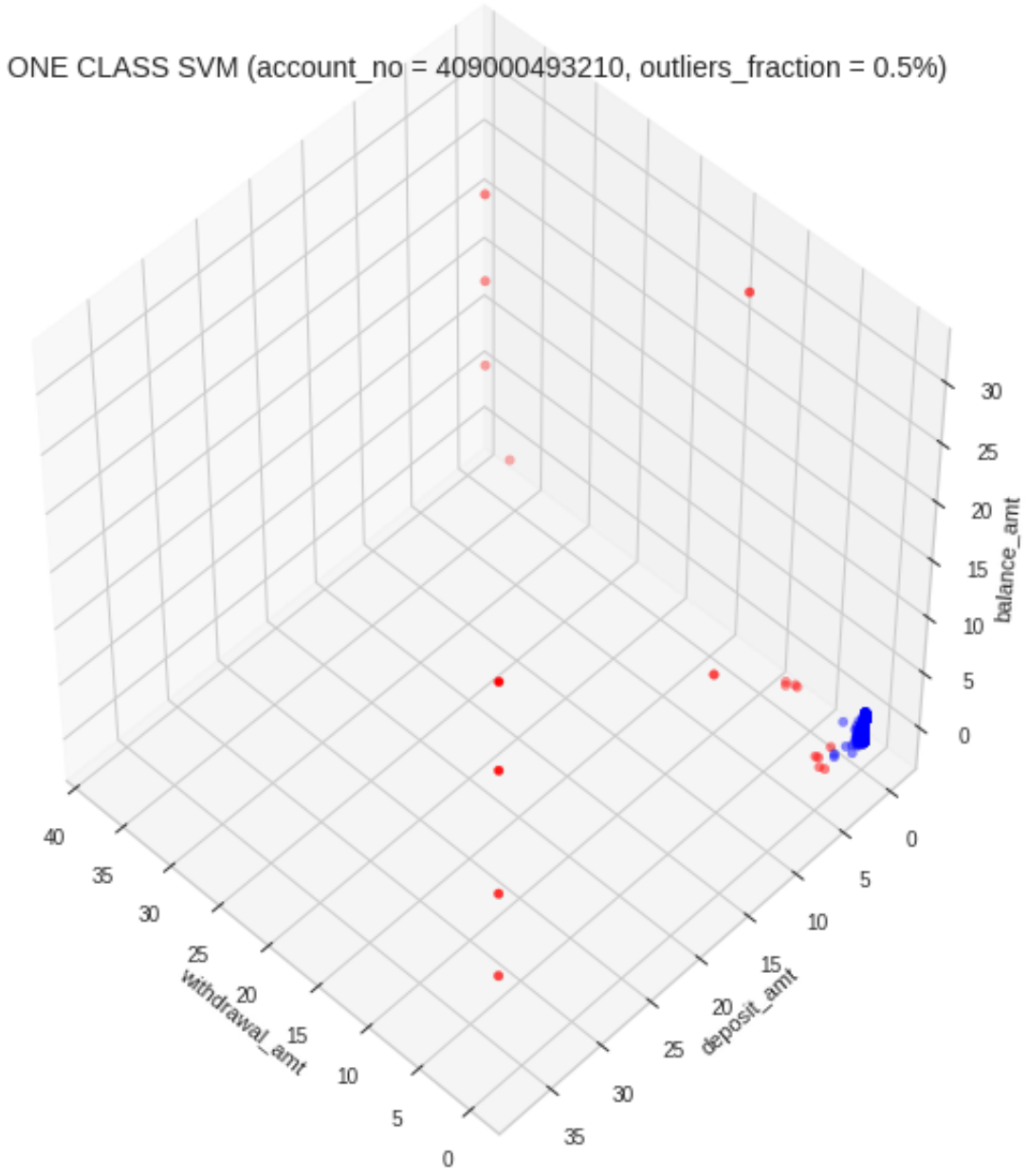
```
0    5989
1      25
Name: anomaly_svm, dtype: int64
```

```
bank_main['svm_5'] = 0
bank_main.loc[acc5_svm_scaled.index,'svm_5'] = acc5_svm_scaled['anomaly_svm']
bank_main['svm_5'].value_counts()
```

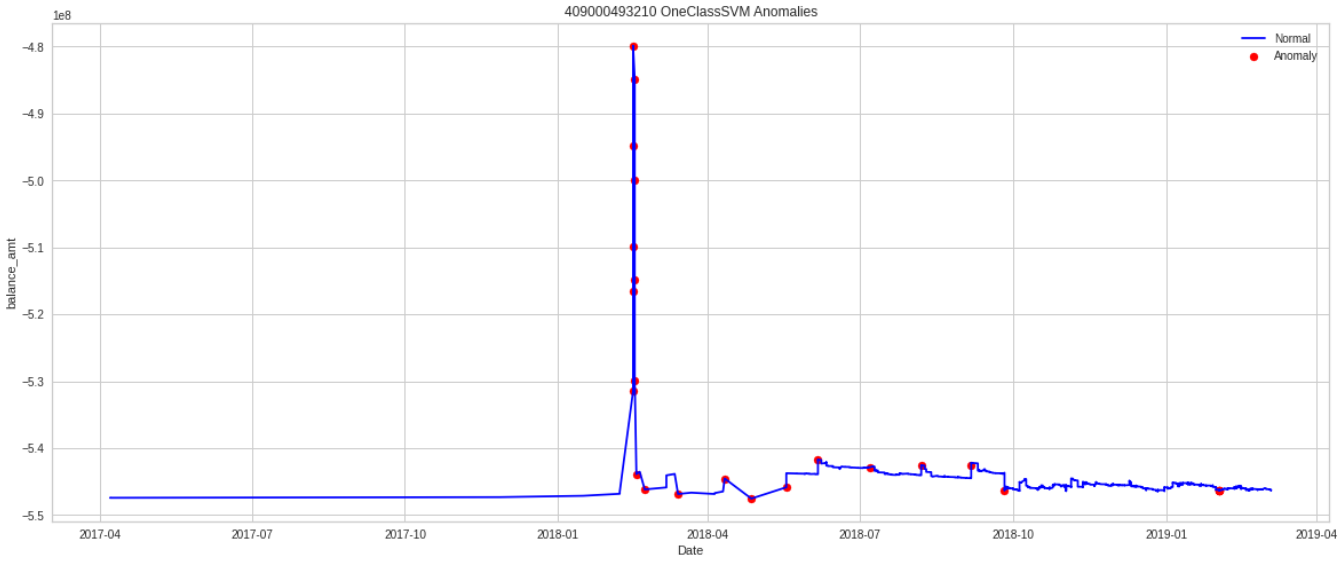
```
0    116176
1        25
Name: svm_5, dtype: int64
```

```
labels = acc5_svm_scaled.anomaly_svm
colors = {0:'blue', 1:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc5_svm_scaled.iloc[:,3], acc5_svm_scaled.iloc[:,4], acc5_svm_scal
ax.set_title(f'ONE CLASS SVM (account_no = {accounts[4]}, outliers_fraction = 
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
df = acc5_svm.copy()
a= df.loc[df['anomaly_svm']==1, ['date', 'balance_amt']]
plt.figure(figsize=(20,8))
plt.plot(df['date'], df['balance_amt'], color='blue', label='Normal')
plt.scatter(a['date'], a['balance_amt'], color='red', label='Anomaly')
plt.title(f'{accounts[4]} OneClassSVM Anomalies')
plt.xlabel('Date')
plt.ylabel('balance_amt')
plt.legend()
plt.show()
```



(VI) OneClassSVM account_no: 409000438611

```
acc6_svm = acc6.copy()
scaler = StandardScaler()
acc6_svm_scaled = pd.DataFrame(scaler.fit_transform(acc6_svm[acc6.columns[2:]]))
acc6_svm_scaled.set_index(acc6_svm.index, drop=True, inplace=True)
acc6_svm_scaled.head(3)
```

	day_diff	weekend_date	weekend_value_date	withdrawal_amt	deposit_amt
2990	0.0	-0.280204	-0.280204	-0.217132	52.87383
2991	0.0	-0.280204	-0.280204	27.304861	-0.32047
2992	0.0	-0.280204	-0.280204	8.251173	-0.32047

```
outliers_fraction = .005
model = OneClassSVM(nu=outliers_fraction, kernel='rbf', gamma=.01)
model.fit(acc6_svm_scaled)
```

```
OneClassSVM(cache_size=200, coef0=0.0, degree=3, gamma=0.01, kernel='rbf',
            max_iter=-1, nu=0.005, shrinking=True, tol=0.001, verbose=False
```

```
acc6_svm_scaled['anomaly_svm'] = pd.Series(model.predict(acc6_svm_scaled)).app
acc6_svm['anomaly_svm'] = acc6_svm_scaled['anomaly_svm']
acc6_svm_scaled['anomaly_svm'].value_counts()
```

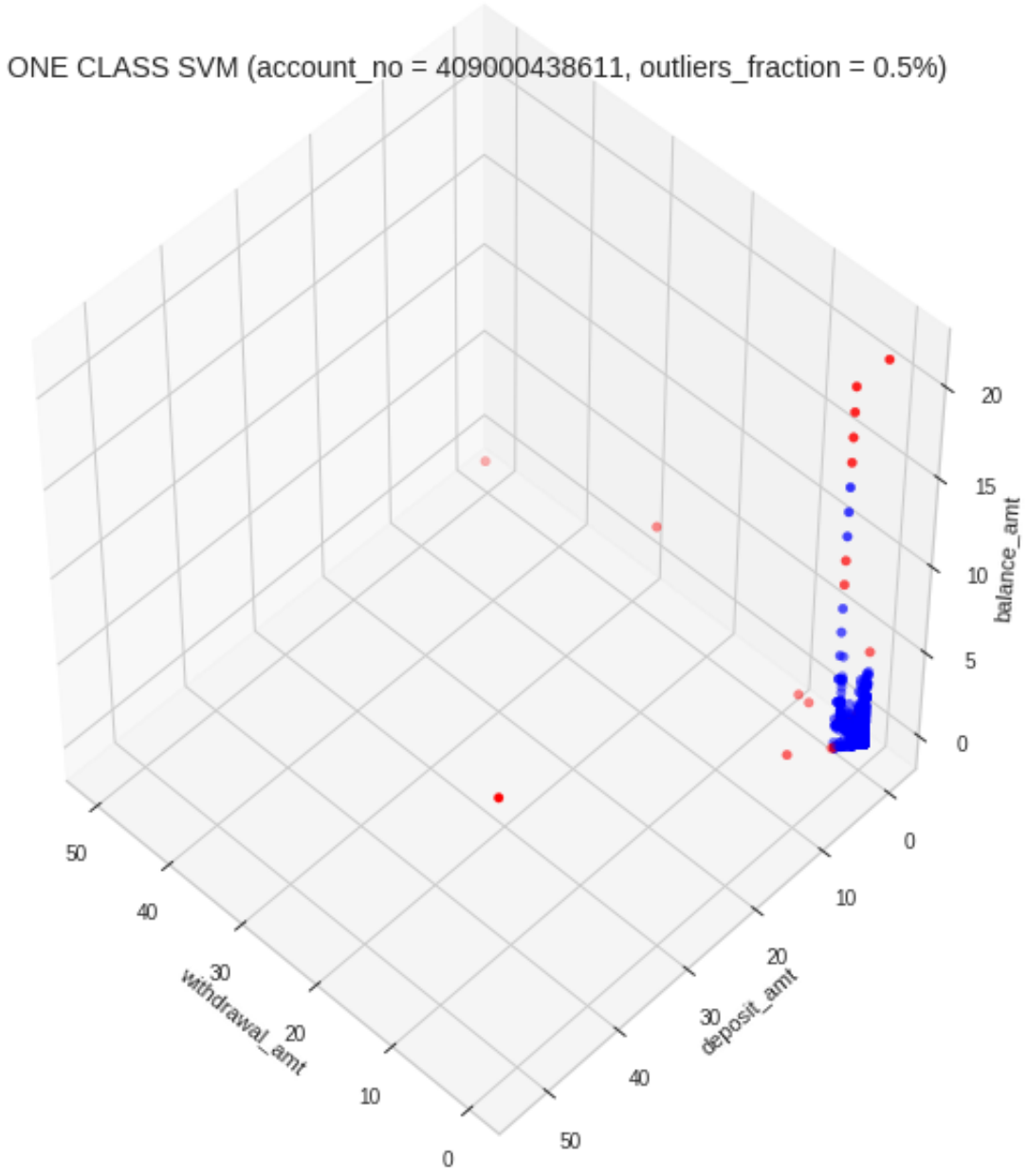
```
0    4559
1      29
Name: anomaly_svm, dtype: int64
```

```
bank_main['svm_6'] = 0
bank_main.loc[acc6_svm_scaled.index,'svm_6'] = acc6_svm_scaled['anomaly_svm']
bank_main['svm_6'].value_counts()
```

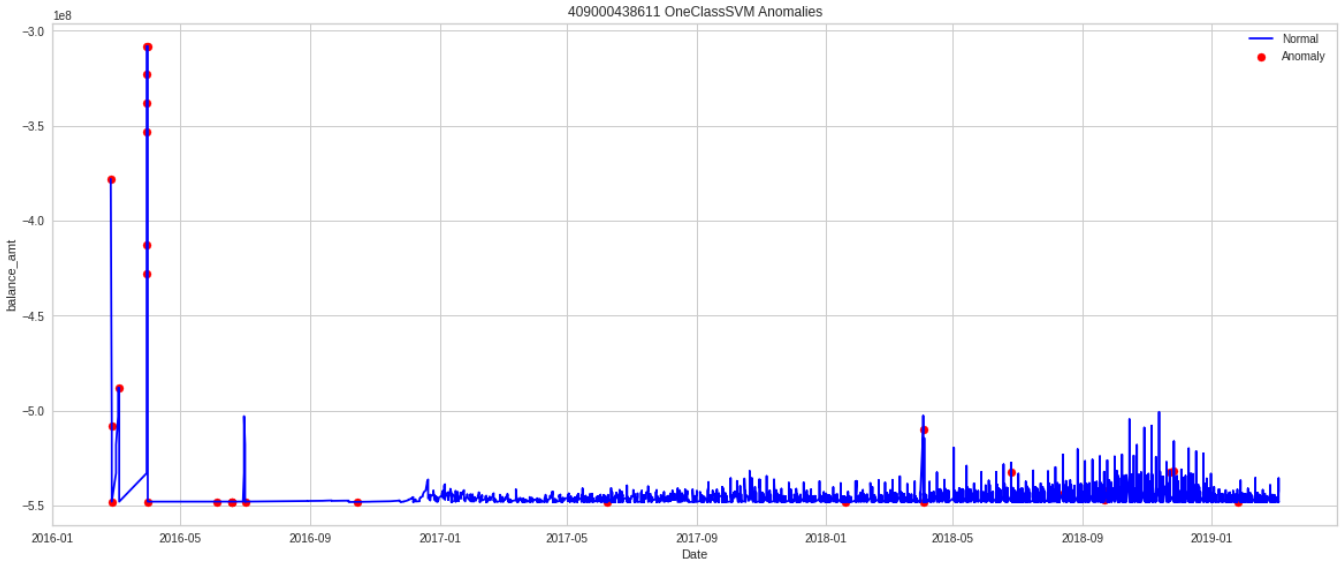
```
0    116172
1        29
Name: svm_6, dtype: int64
```

```
labels = acc6_svm_scaled.anomaly_svm
colors = {0:'blue', 1:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc6_svm_scaled.iloc[:,3], acc6_svm_scaled.iloc[:,4], acc6_svm_scal
ax.set_title(f'ONE CLASS SVM (account_no = {accounts[5]}, outliers_fraction = 
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
df = acc6_svm.copy()
a= df.loc[df['anomaly_svm']==1, ['date', 'balance_amt']]
plt.figure(figsize=(20,8))
plt.plot(df['date'], df['balance_amt'], color='blue', label='Normal')
plt.scatter(a['date'], a['balance_amt'], color='red', label='Anomaly')
plt.title(f'{accounts[5]} OneClassSVM Anomalies')
plt.xlabel('Date')
plt.ylabel('balance_amt')
plt.legend()
plt.show()
```



(VII) OneClassSVM account_no: 409000611074

```
acc7_svm = acc7.copy()
scaler = StandardScaler()
acc7_svm_scaled = pd.DataFrame(scaler.fit_transform(acc7_svm[acc7.columns[2:]]))
acc7_svm_scaled.set_index(acc7_svm.index, drop=True, inplace=True)
acc7_svm_scaled.head(3)
```

	day_diff	weekend_date	weekend_value_date	withdrawal_amt	deposit_amt	b
0	0.0	-0.269481	-0.269481	-0.687913	3.664767	
1	0.0	-0.269481	-0.269481	-0.687913	3.664767	
2	0.0	-0.269481	-0.269481	-0.687913	1.550196	

```
outliers_fraction = .01
model = OneClassSVM(nu=outliers_fraction, kernel='rbf', gamma=.01)
model.fit(acc7_svm_scaled)
```

```
OneClassSVM(cache_size=200, coef0=0.0, degree=3, gamma=0.01, kernel='rbf',
            max_iter=-1, nu=0.01, shrinking=True, tol=0.001, verbose=False)
```

```
acc7_svm_scaled['anomaly_svm'] = pd.Series(model.predict(acc7_svm_scaled)).app
acc7_svm['anomaly_svm'] = acc7_svm_scaled['anomaly_svm']
acc7_svm_scaled['anomaly_svm'].value_counts()
```

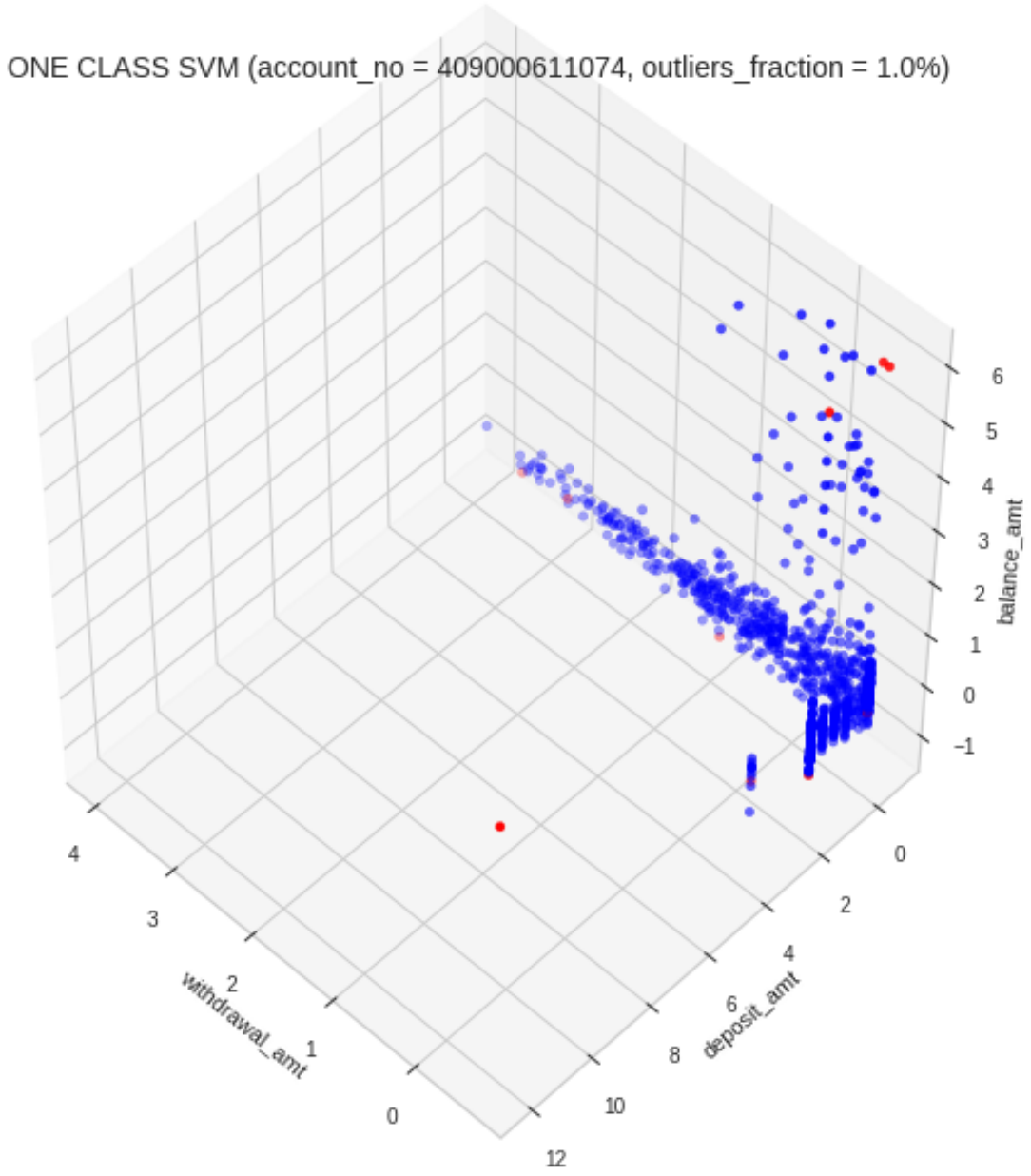
```
0    1082
1      11
Name: anomaly_svm, dtype: int64
```

```
bank_main['svm_7'] = 0
bank_main.loc[acc7_svm_scaled.index,'svm_7'] = acc7_svm_scaled['anomaly_svm']
bank_main['svm_7'].value_counts()
```

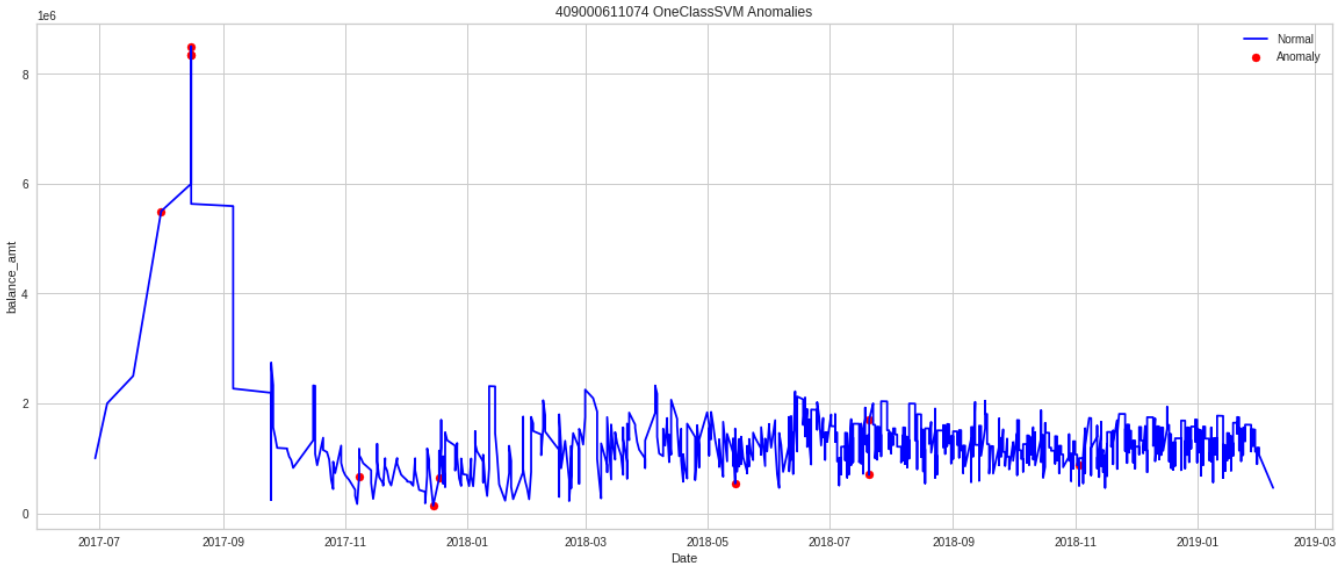
```
0    116190
1        11
Name: svm_7, dtype: int64
```

```
labels = acc7_svm_scaled.anomaly_svm
colors = {0:'blue', 1:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc7_svm_scaled.iloc[:,3], acc7_svm_scaled.iloc[:,4], acc7_svm_scal
ax.set_title(f'ONE CLASS SVM (account_no = {accounts[6]}, outliers_fraction = 
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
df = acc7_svm.copy()
a= df.loc[df['anomaly_svm']==1, ['date', 'balance_amt']]
plt.figure(figsize=(20,8))
plt.plot(df['date'], df['balance_amt'], color='blue', label='Normal')
plt.scatter(a['date'], a['balance_amt'], color='red', label='Anomaly')
plt.title(f'{accounts[6]} OneClassSVM Anomalies')
plt.xlabel('Date')
plt.ylabel('balance_amt')
plt.legend()
plt.show()
```



(VIII) OneClassSVM account_no: 409000493201

```
acc8_svm = acc8.copy()
scaler = StandardScaler()
acc8_svm_scaled = pd.DataFrame(scaler.fit_transform(acc8_svm[acc8.columns[2:]]))
acc8_svm_scaled.set_index(acc8_svm.index, drop=True, inplace=True)
acc8_svm_scaled.head(3)
```

	day_diff	weekend_date	weekend_value_date	withdrawal_amt	deposit_amt
1093	0.0	-0.261873	-0.261873	-0.450731	3.00717
1094	0.0	-0.261873	-0.261873	-0.446770	-0.67472
1095	0.0	-0.261873	-0.261873	-0.449547	-0.67472

```
outliers_fraction = .01
model = OneClassSVM(nu=outliers_fraction, kernel='rbf', gamma=.01)
model.fit(acc8_svm_scaled)
```

```
OneClassSVM(cache_size=200, coef0=0.0, degree=3, gamma=0.01, kernel='rbf',
            max_iter=-1, nu=0.01, shrinking=True, tol=0.001, verbose=False)
```

```
acc8_svm_scaled['anomaly_svm'] = pd.Series(model.predict(acc8_svm_scaled)).app
acc8_svm['anomaly_svm'] = acc8_svm_scaled['anomaly_svm']
acc8_svm_scaled['anomaly_svm'].value_counts()
```

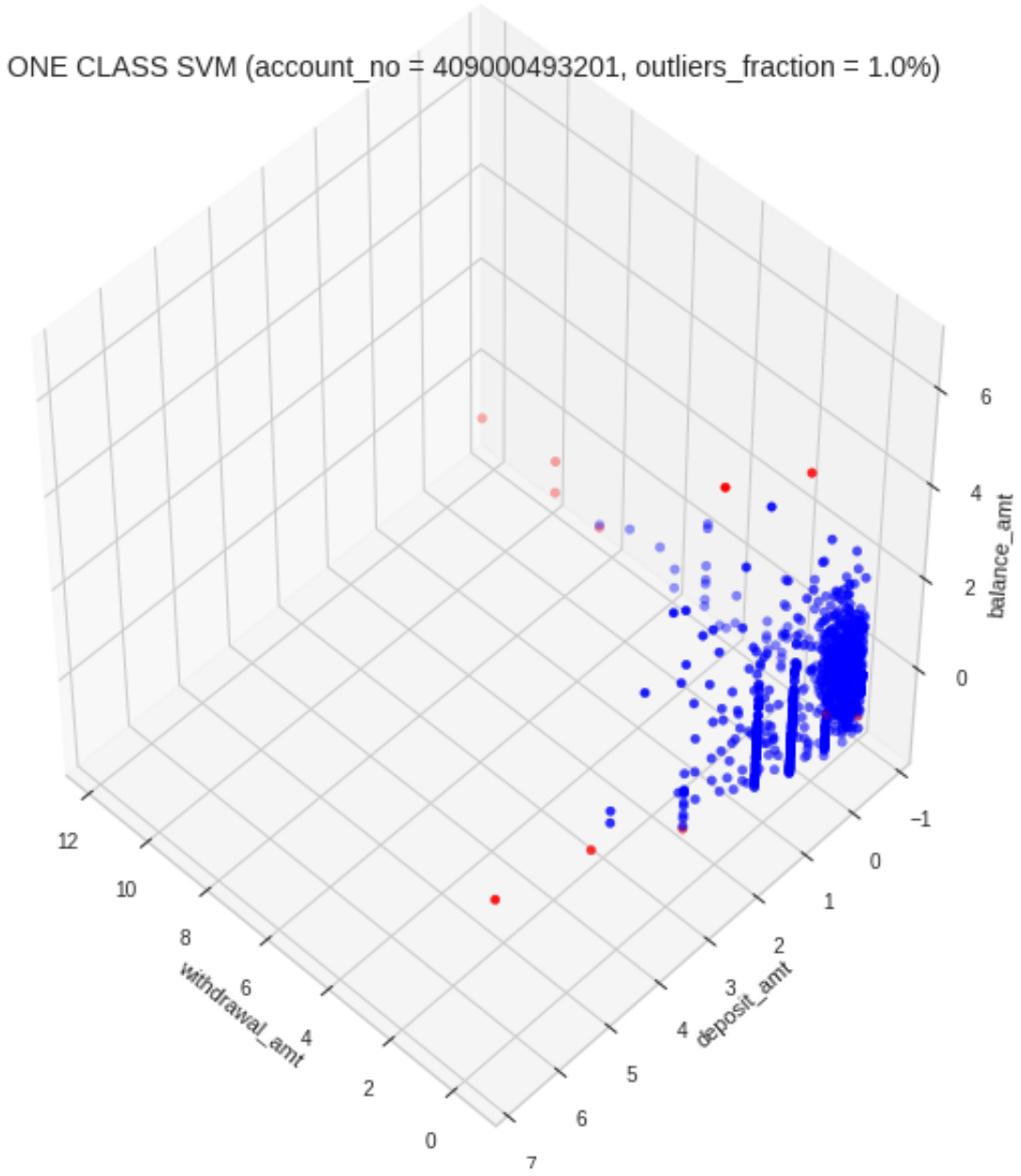
```
0    1033
1      11
Name: anomaly_svm, dtype: int64
```

```
bank_main['svm_8'] = 0
bank_main.loc[acc8_svm_scaled.index,'svm_8'] = acc8_svm_scaled['anomaly_svm']
bank_main['svm_8'].value_counts()
```

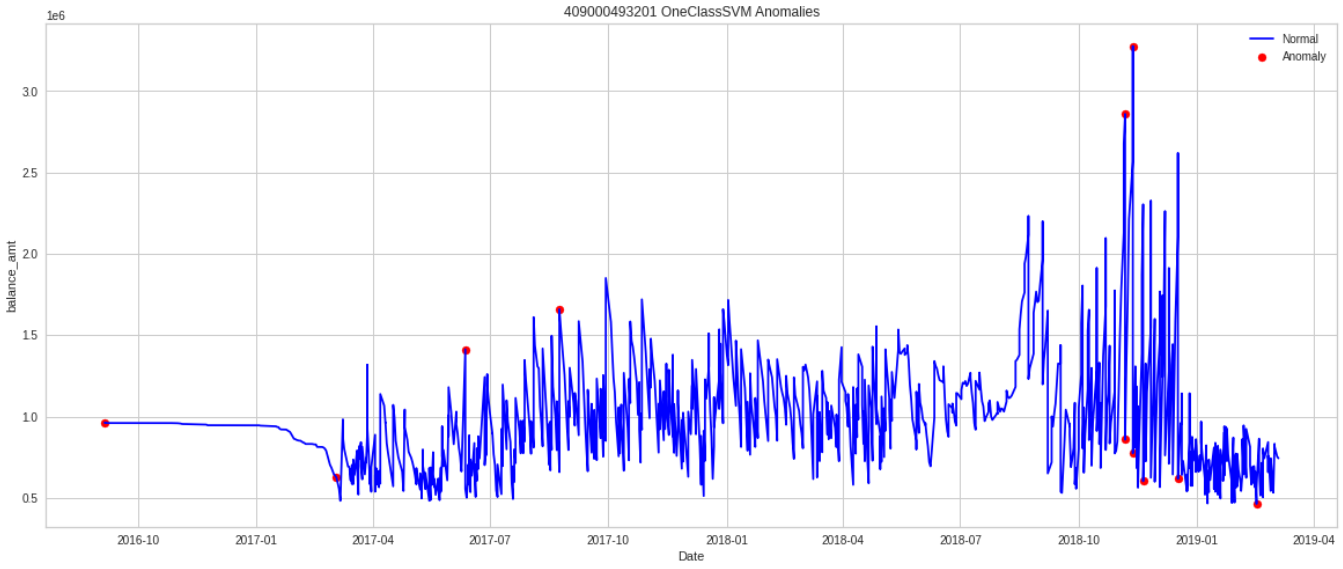
```
0    116190
1        11
Name: svm_8, dtype: int64
```

```
labels = acc8_svm_scaled.anomaly_svm
colors = {0:'blue', 1:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc8_svm_scaled.iloc[:,3], acc8_svm_scaled.iloc[:,4], acc8_svm_scal
ax.set_title(f'ONE CLASS SVM (account_no = {accounts[7]}, outliers_fraction = 
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
df = acc8_svm.copy()
a= df.loc[df['anomaly_svm']==1, ['date', 'balance_amt']]
plt.figure(figsize=(20,8))
plt.plot(df['date'], df['balance_amt'], color='blue', label='Normal')
plt.scatter(a['date'], a['balance_amt'], color='red', label='Anomaly')
plt.title(f'{accounts[7]} OneClassSVM Anomalies')
plt.xlabel('Date')
plt.ylabel('balance_amt')
plt.legend()
plt.show()
```



(IX) OneClassSVM account_no: 409000425051

```
acc9_svm = acc9.copy()
scaler = StandardScaler()
acc9_svm_scaled = pd.DataFrame(scaler.fit_transform(acc9_svm[acc9.columns[2:]]))
acc9_svm_scaled.set_index(acc9_svm.index, drop=True, inplace=True)
acc9_svm_scaled.head(3)
```

	day_diff	weekend_date	weekend_value_date	withdrawal_amt	deposit_amt
2137	0.0	-0.429695	-0.429695	-0.038344	-0.02322
2138	0.0	-0.429695	-0.429695	-0.038344	-0.05979
2139	0.0	-0.429695	-0.429695	-0.038344	-0.02322

```
outliers_fraction = .01
model = OneClassSVM(nu=outliers_fraction, kernel='rbf', gamma=.01)
model.fit(acc9_svm_scaled)
```

```
OneClassSVM(cache_size=200, coef0=0.0, degree=3, gamma=0.01, kernel='rbf',
            max_iter=-1, nu=0.01, shrinking=True, tol=0.001, verbose=False)
```

```
acc9_svm_scaled['anomaly_svm'] = pd.Series(model.predict(acc9_svm_scaled)).app
acc9_svm['anomaly_svm'] = acc9_svm_scaled['anomaly_svm']
acc9_svm_scaled['anomaly_svm'].value_counts()
```

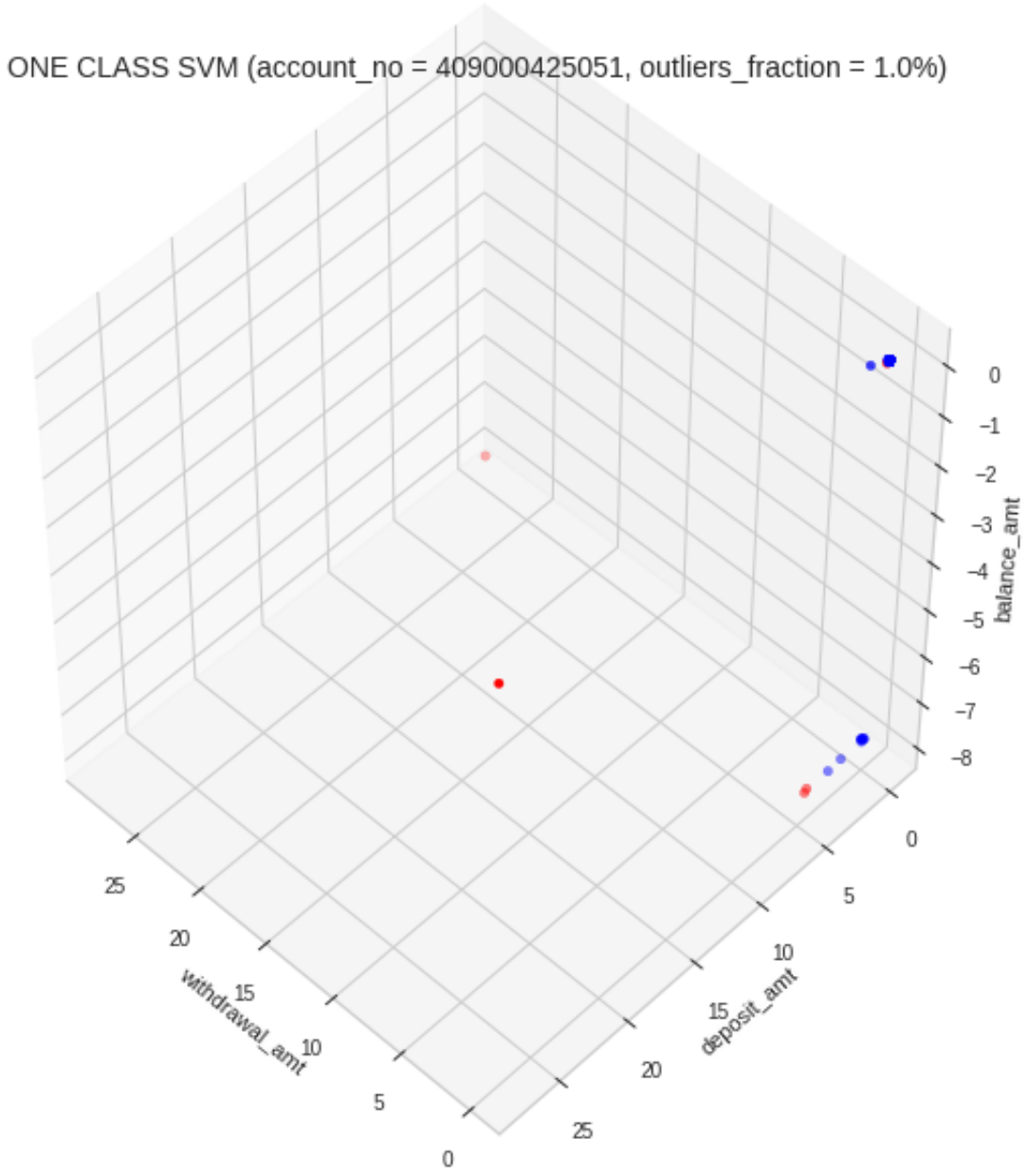
```
0    797
1      5
Name: anomaly_svm, dtype: int64
```

```
bank_main['svm_9'] = 0
bank_main.loc[acc9_svm_scaled.index,'svm_9'] = acc9_svm_scaled['anomaly_svm']
bank_main['svm_9'].value_counts()
```

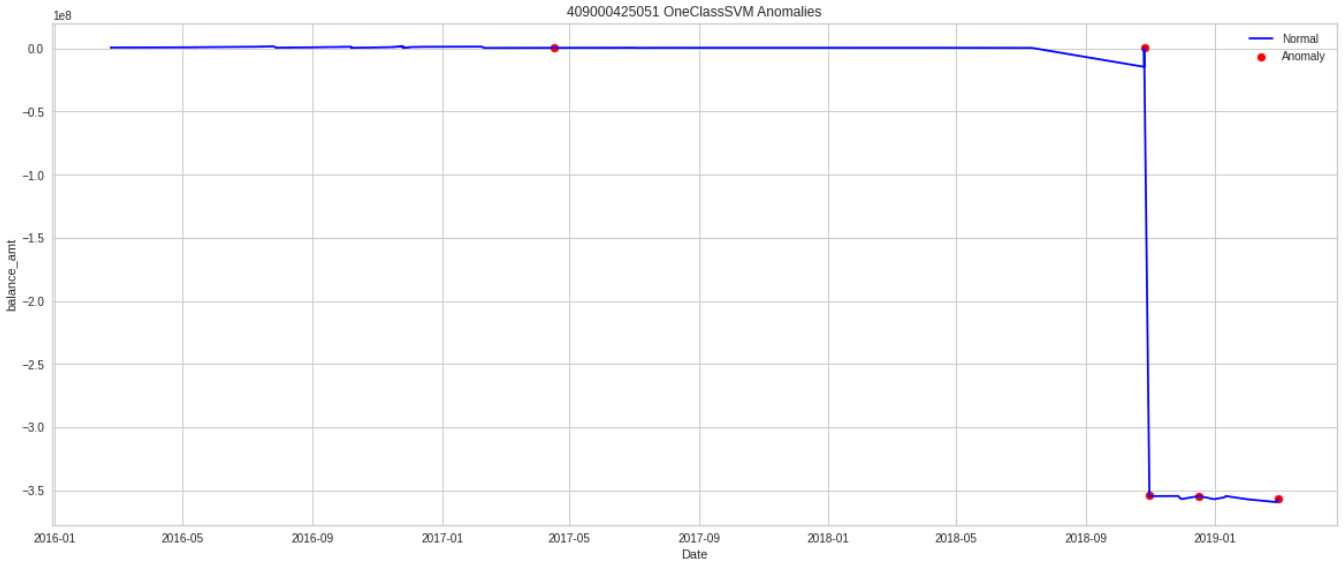
```
0    116196
1         5
Name: svm_9, dtype: int64
```

```
labels = acc9_svm_scaled.anomaly_svm
colors = {0:'blue', 1:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc9_svm_scaled.iloc[:,3], acc9_svm_scaled.iloc[:,4], acc9_svm_scal
ax.set_title(f'ONE CLASS SVM (account_no = {accounts[8]}, outliers_fraction = 
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
df = acc9_svm.copy()
a= df.loc[df['anomaly_svm']==1, ['date', 'balance_amt']]
plt.figure(figsize=(20,8))
plt.plot(df['date'], df['balance_amt'], color='blue', label='Normal')
plt.scatter(a['date'], a['balance_amt'], color='red', label='Anomaly')
plt.title(f'{accounts[8]} OneClassSVM Anomalies')
plt.xlabel('Date')
plt.ylabel('balance_amt')
plt.legend()
plt.show()
```



(X) OneClassSVM account_no: 409000405747

```
acc10_svm = acc10.copy()
scaler = StandardScaler()
acc10_svm_scaled = pd.DataFrame(scaler.fit_transform(acc10_svm[acc10.columns[2:
acc10_svm_scaled.set_index(acc10_svm.index, drop=True, inplace=True)
acc10_svm_scaled.head(3)
```

	day_diff	weekend_date	weekend_value_date	withdrawal_amt	deposit_am
2939	0.0	2.318405	2.318405	5.917619	-0.16033
2940	0.0	2.318405	2.318405	0.795991	-0.16033
2941	0.0	2.318405	2.318405	-0.296882	-0.16033

```
outliers_fraction = .09
model = OneClassSVM(nu=outliers_fraction, kernel='rbf', gamma=.01)
model.fit(acc10_svm_scaled)
```

```
OneClassSVM(cache_size=200, coef0=0.0, degree=3, gamma=0.01, kernel='rbf',
            max_iter=-1, nu=0.09, shrinking=True, tol=0.001, verbose=False)
```

```
acc10_svm_scaled['anomaly_svm'] = pd.Series(model.predict(acc10_svm_scaled)).a
acc10_svm['anomaly_svm'] = acc10_svm_scaled['anomaly_svm']
acc10_svm_scaled['anomaly_svm'].value_counts()
```

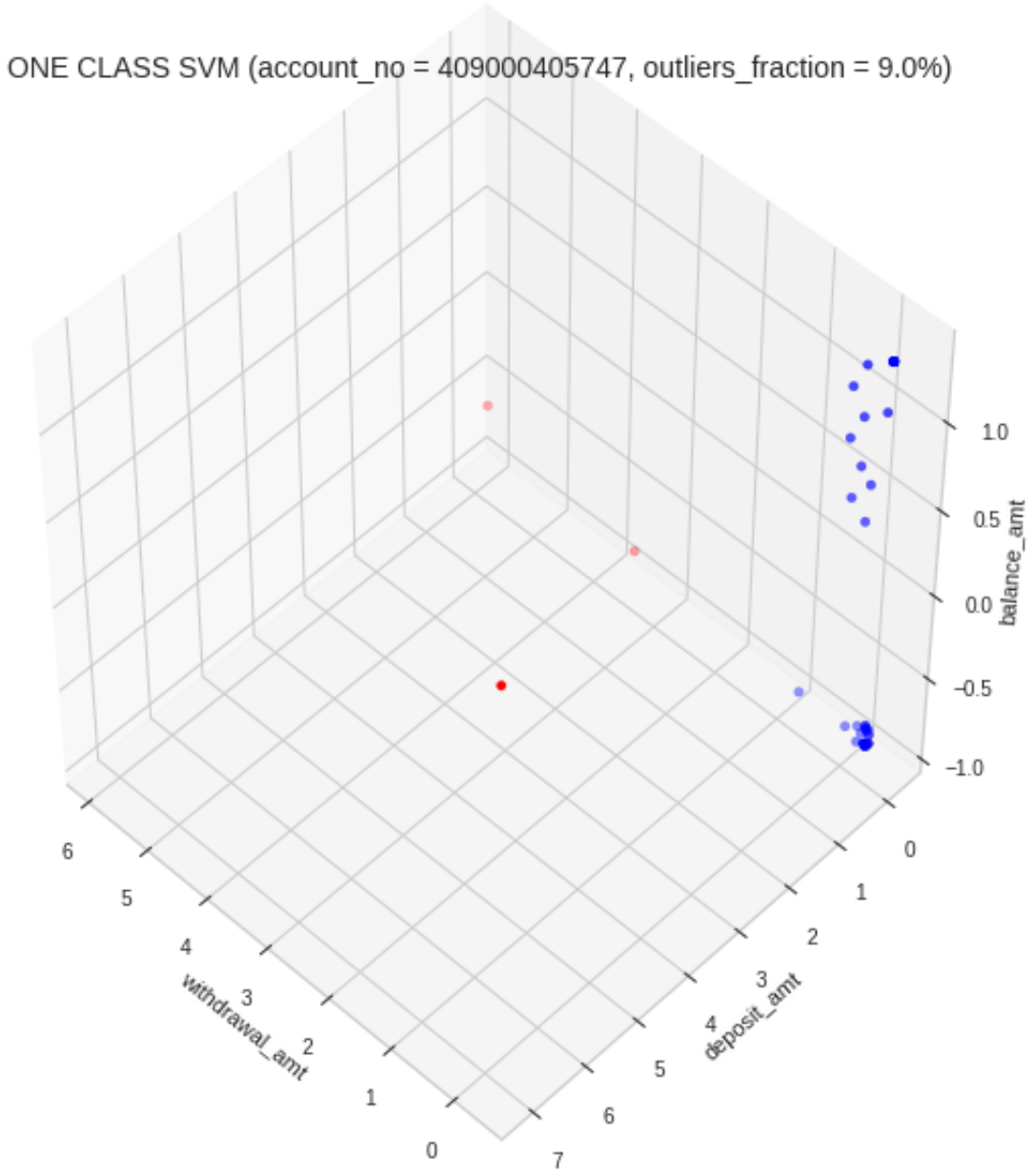
```
0    47
1     4
Name: anomaly_svm, dtype: int64
```

```
bank_main['svm_10'] = 0
bank_main.loc[acc10_svm_scaled.index,'svm_10'] = acc10_svm_scaled['anomaly_svm
bank_main['svm_10'].value_counts()
```

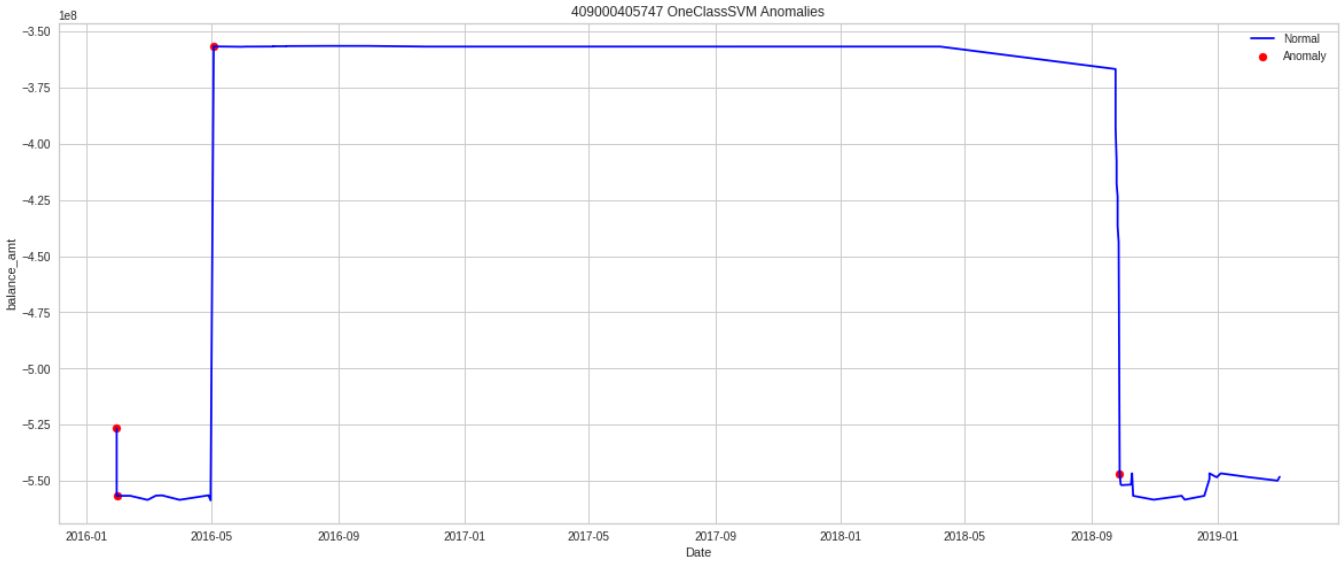
```
0    116197
1         4
Name: svm_10, dtype: int64
```

```
labels = acc10_svm_scaled.anomaly_svm
colors = {0:'blue', 1:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc10_svm_scaled.iloc[:,3], acc10_svm_scaled.iloc[:,4], acc10_svm_s
ax.set_title(f'ONE CLASS SVM (account_no = {accounts[9]}, outliers_fraction = 
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
df = acc10_svm.copy()
a= df.loc[df['anomaly_svm']==1, ['date', 'balance_amt']]
plt.figure(figsize=(20,8))
plt.plot(df['date'], df['balance_amt'], color='blue', label='Normal')
plt.scatter(a['date'], a['balance_amt'], color='red', label='Anomaly')
plt.title(f'{accounts[9]} OneClassSVM Anomalies')
plt.xlabel('Date')
plt.ylabel('balance_amt')
plt.legend()
plt.show()
```




```
bank_main['accounts_SVM'] = bank_main.svm_1 + bank_main.svm_2 + bank_main.svm_
```

```
bank_main['accounts_SVM'].value_counts()
```

```
0    115613
1       588
Name: accounts_SVM, dtype: int64
```

iii. Gaussian Distribution Anomaly Detection (Elliptic Envelope)

(I) Gaussian Distribution account_no: 409000405747

```
acc1_gauss = acc1.copy()
scaler = StandardScaler()
acc1_gauss_scaled = pd.DataFrame(scaler.fit_transform(acc1_gauss[acc1.columns[2
acc1_gauss_scaled.set_index(acc1_gauss.index, drop=True, inplace=True)
acc1_gauss_scaled.head(3)
```

	day_diff	weekend_date	weekend_value_date	withdrawal_amt	deposit_ar
37582	-0.009703	-0.327498	-0.327574	-0.363895	-0.0352
37583	-0.009703	-0.327498	-0.327574	-0.363895	-0.1051
37584	-0.009703	-0.327498	-0.327574	-0.363895	-0.2422

```
outliers_fraction = .005
model = EllipticEnvelope(contamination=outliers_fraction)
model.fit(acc1_gauss_scaled)
```

```
EllipticEnvelope(assume_centered=False, contamination=0.005, random_state=N
                 store_precision=True, support_fraction=None)
```

```
acc1_gauss_scaled['anomaly_gauss'] = pd.Series(model.predict(acc1_gauss_scaled
acc1_gauss['anomaly_gauss'] = acc1_gauss_scaled['anomaly_gauss']
acc1_gauss_scaled['anomaly_gauss'].value_counts()
```

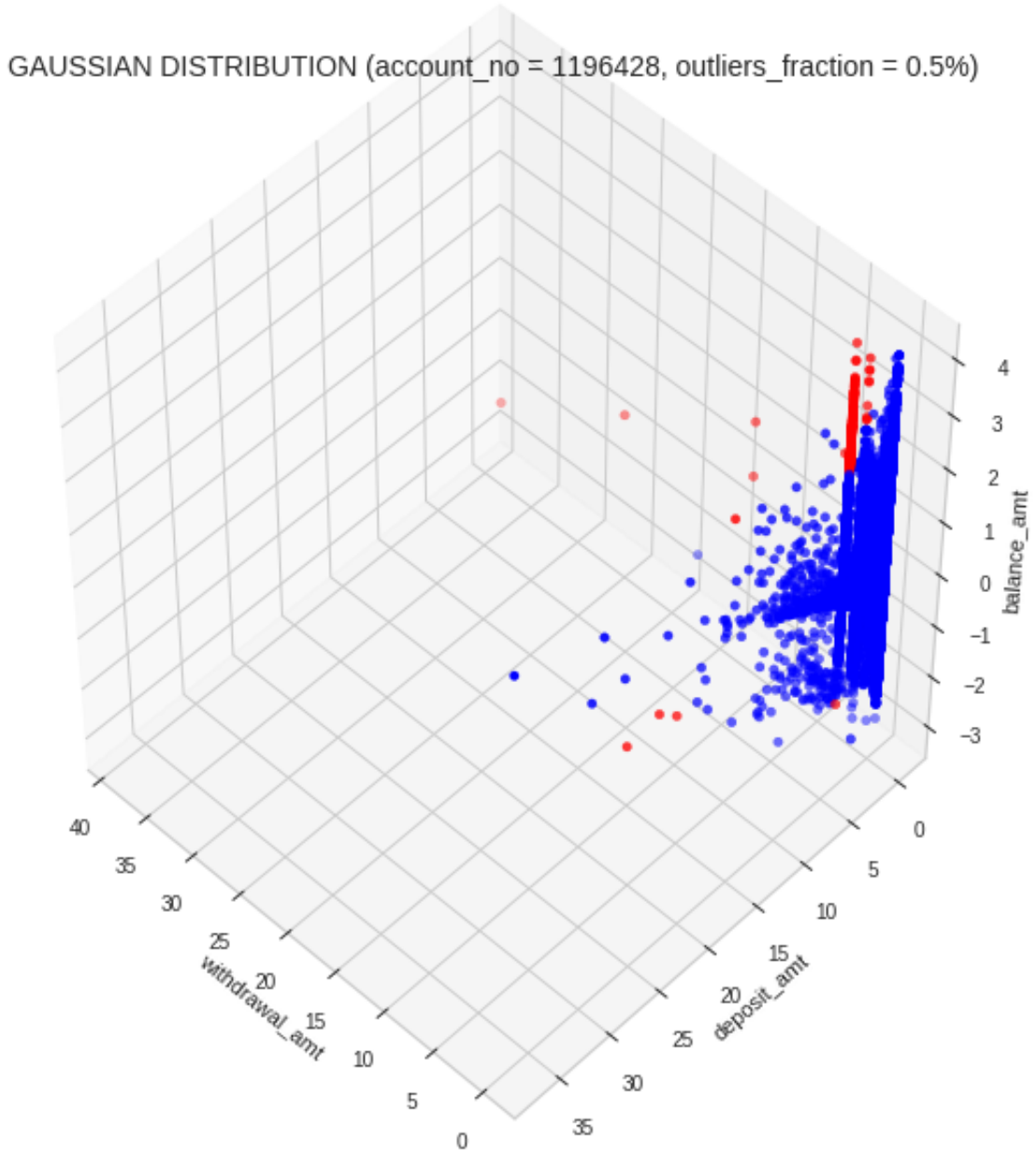
```
0    48535
1      244
Name: anomaly_gauss, dtype: int64
```

```
bank_main['gauss_1'] = 0
bank_main.loc[acc1_gauss_scaled.index,'gauss_1'] = acc1_gauss_scaled['anomaly_
bank_main['gauss_1'].value_counts()
```

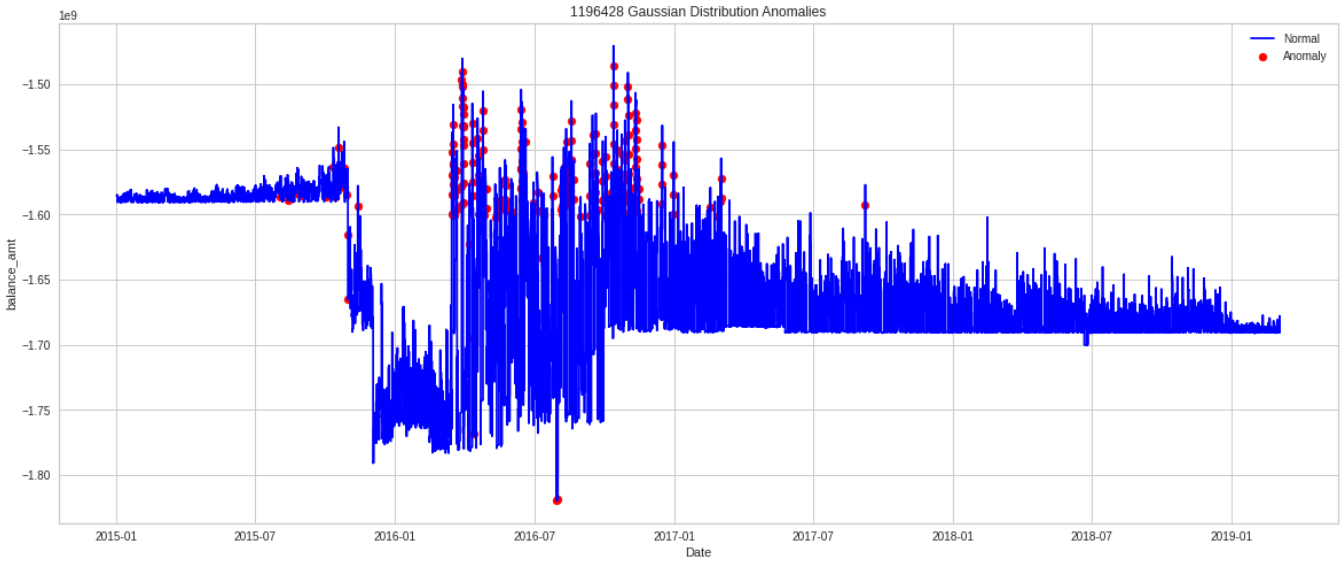
```
0    115957
1       244
Name: gauss_1, dtype: int64
```

```
labels = acc1_gauss_scaled.anomaly_gauss
colors = {0:'blue', 1:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc1_gauss_scaled.iloc[:,3], acc1_gauss_scaled.iloc[:,4], acc1_gaus
ax.set_title(f'GAUSSIAN DISTRIBUTION (account_no = {accounts[0]}, outliers_fra
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
df = acc1_gauss.copy()
a= df.loc[df['anomaly_gauss']==1, ['date', 'balance_amt']]
plt.figure(figsize=(20,8))
plt.plot(df['date'], df['balance_amt'], color='blue', label='Normal')
plt.scatter(a['date'], a['balance_amt'], color='red', label='Anomaly')
plt.title(f'{accounts[0]} Gaussian Distribution Anomalies')
plt.xlabel('Date')
plt.ylabel('balance_amt')
plt.legend()
plt.show()
```



(II) Gaussian Distribution account_no: 409000362497

```
acc2_gauss = acc2.copy()
scaler = StandardScaler()
acc2_gauss_scaled = pd.DataFrame(scaler.fit_transform(acc2_gauss[acc2.columns[2
acc2_gauss_scaled.set_index(acc2_gauss.index, drop=True, inplace=True)
acc2_gauss_scaled.head(3)
```

	day_diff	weekend_date	weekend_value_date	withdrawal_amt	deposit_ar
86361	-0.020357	-0.286669	-0.286463	-0.297246	1.00303
86362	-0.020357	-0.286669	-0.286463	-0.297246	1.00303
86363	-0.020357	-0.286669	-0.286463	-0.297246	1.00303

```
outliers_fraction = .005
model = EllipticEnvelope(contamination=outliers_fraction)
model.fit(acc2_gauss_scaled)
```

```
EllipticEnvelope(assume_centered=False, contamination=0.005, random_state=N
                 store_precision=True, support_fraction=None)
```

```
acc2_gauss_scaled['anomaly_gauss'] = pd.Series(model.predict(acc2_gauss_scaled
acc2_gauss['anomaly_gauss'] = acc2_gauss_scaled['anomaly_gauss']
acc2_gauss_scaled['anomaly_gauss'].value_counts()
```

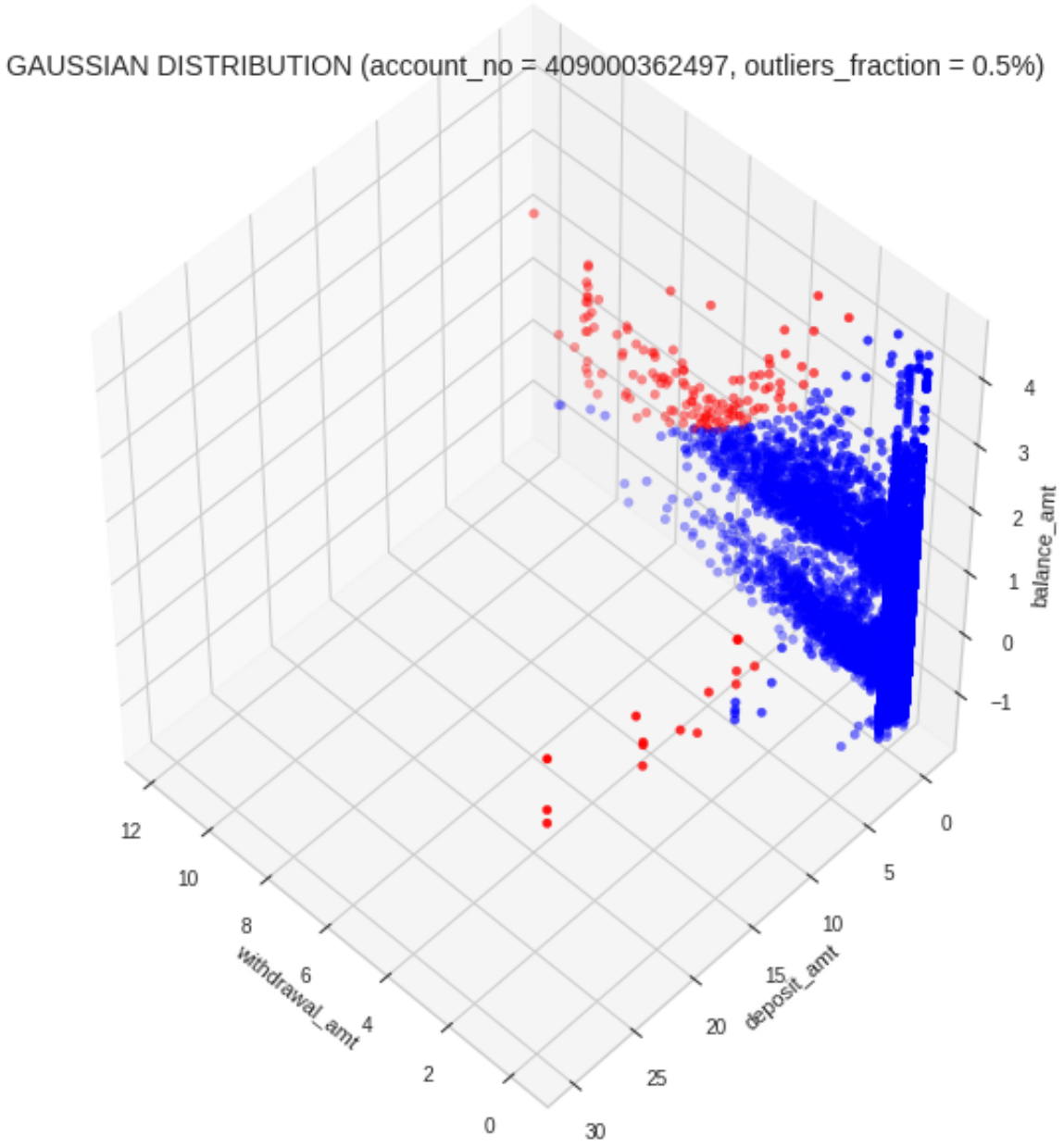
```
0    29690
1      150
Name: anomaly_gauss, dtype: int64
```

```
bank_main['gauss_2'] = 0
bank_main.loc[acc2_gauss_scaled.index,'gauss_2'] = acc2_gauss_scaled['anomaly_
bank_main['gauss_2'].value_counts()
```

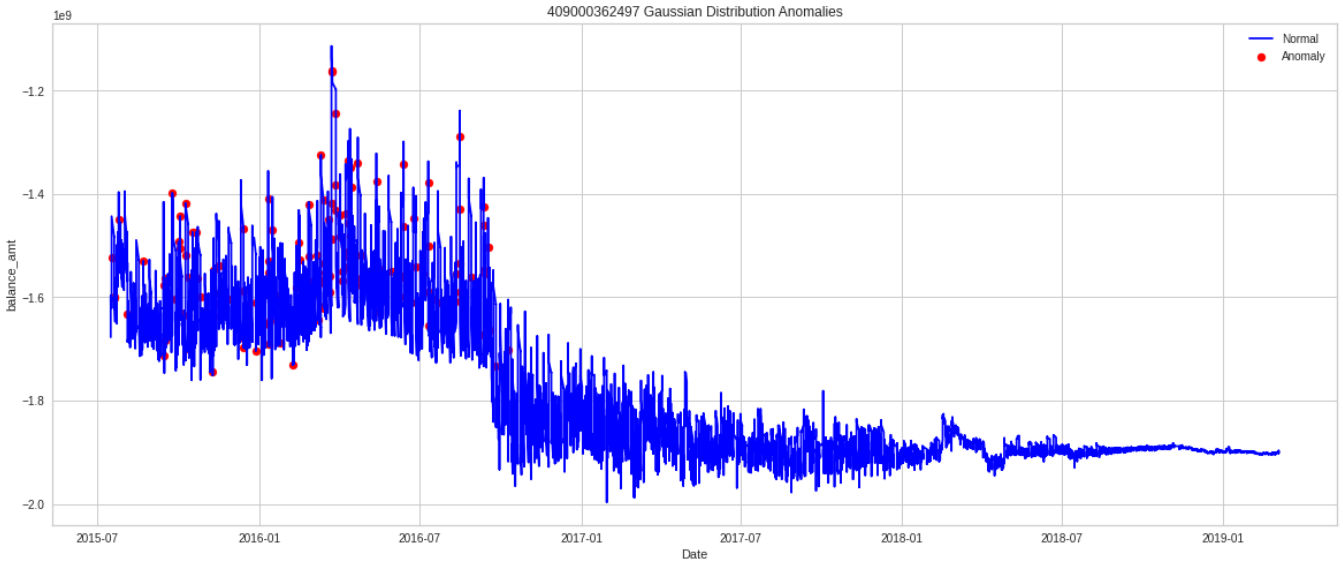
```
0    116051
1       150
Name: gauss_2, dtype: int64
```

```
labels = acc2_gauss_scaled.anomaly_gauss
colors = {0:'blue', 1:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc2_gauss_scaled.iloc[:,3], acc2_gauss_scaled.iloc[:,4], acc2_gaus
ax.set_title(f'GAUSSIAN DISTRIBUTION (account_no = {accounts[1]}, outliers_fra
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
df = acc2_gauss.copy()
a= df.loc[df['anomaly_gauss']==1, ['date', 'balance_amt']]
plt.figure(figsize=(20,8))
plt.plot(df['date'], df['balance_amt'], color='blue', label='Normal')
plt.scatter(a['date'], a['balance_amt'], color='red', label='Anomaly')
plt.title(f'{accounts[1]} Gaussian Distribution Anomalies')
plt.xlabel('Date')
plt.ylabel('balance_amt')
plt.legend()
plt.show()
```



(III) Gaussian Distribution account_no: 409000438620

```
acc3_gauss = acc3.copy()
scaler = StandardScaler()
acc3_gauss_scaled = pd.DataFrame(scaler.fit_transform(acc3_gauss[acc3.columns[2
acc3_gauss_scaled.set_index(acc3_gauss.index, drop=True, inplace=True)
acc3_gauss_scaled.head(3)
```

	day_diff	weekend_date	weekend_value_date	withdrawal_amt	deposit_ar
13592	0.0	-0.310493	-0.310493	-0.199596	68.5563
13593	0.0	-0.310493	-0.310493	15.416558	-0.1612
13594	0.0	-0.310493	-0.310493	-0.199596	1.7307

```
outliers_fraction = .005
model = EllipticEnvelope(contamination=outliers_fraction)
model.fit(acc3_gauss_scaled)
```

```
EllipticEnvelope(assume_centered=False, contamination=0.005, random_state=N
                 store_precision=True, support_fraction=None)
```

```
acc3_gauss_scaled['anomaly_gauss'] = pd.Series(model.predict(acc3_gauss_scaled
acc3_gauss['anomaly_gauss'] = acc3_gauss_scaled['anomaly_gauss']
acc3_gauss_scaled['anomaly_gauss'].value_counts()
```

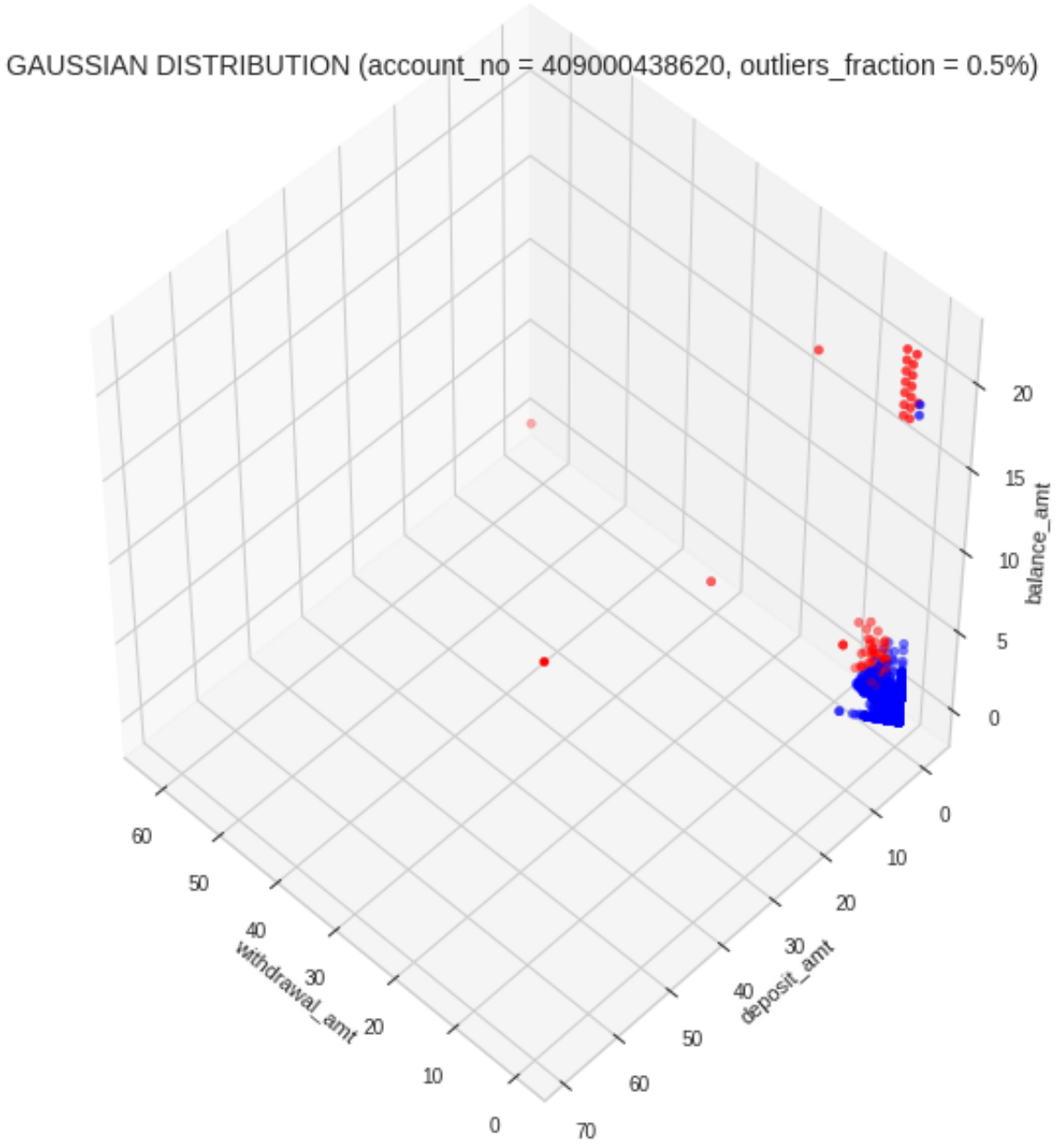
```
0    13386
1       68
Name: anomaly_gauss, dtype: int64
```

```
bank_main['gauss_3'] = 0
bank_main.loc[acc3_gauss_scaled.index,'gauss_3'] = acc3_gauss_scaled['anomaly_
bank_main['gauss_3'].value_counts()
```

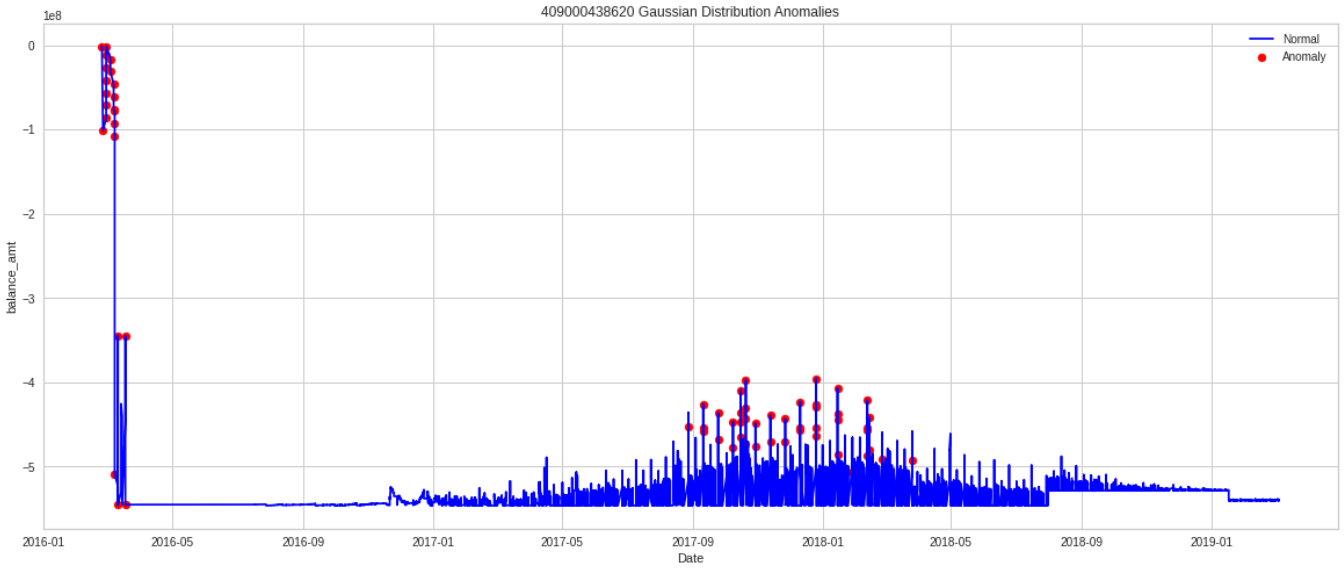
```
0    116133
1        68
Name: gauss_3, dtype: int64
```

```
labels = acc3_gauss_scaled.anomaly_gauss
colors = {0:'blue', 1:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc3_gauss_scaled.iloc[:,3], acc3_gauss_scaled.iloc[:,4], acc3_gaus
ax.set_title(f'GAUSSIAN DISTRIBUTION (account_no = {accounts[2]}, outliers_fra
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
df = acc3_gauss.copy()
a= df.loc[df['anomaly_gauss']==1, ['date', 'balance_amt']]
plt.figure(figsize=(20,8))
plt.plot(df['date'], df['balance_amt'], color='blue', label='Normal')
plt.scatter(a['date'], a['balance_amt'], color='red', label='Anomaly')
plt.title(f'{accounts[2]} Gaussian Distribution Anomalies')
plt.xlabel('Date')
plt.ylabel('balance_amt')
plt.legend()
plt.show()
```



(IV) Gaussian Distribution account_no: 1196711

```
acc4_gauss = acc4.copy()
scaler = StandardScaler()
acc4_gauss_scaled = pd.DataFrame(scaler.fit_transform(acc4_gauss[acc4.columns[2
acc4_gauss_scaled.set_index(acc4_gauss.index, drop=True, inplace=True)
acc4_gauss_scaled.head(3)
```

	day_diff	weekend_date	weekend_value_date	withdrawal_amt	deposit_ar
27046	-0.06111	-0.308943	-0.309496	-0.415321	-0.4182(
27047	-0.06111	-0.308943	-0.309496	-0.415321	-0.4184(
27048	-0.06111	-0.308943	-0.309496	-0.415321	-0.4183(

```
outliers_fraction = .005
model = EllipticEnvelope(contamination=outliers_fraction)
model.fit(acc4_gauss_scaled)
```

```
EllipticEnvelope(assume_centered=False, contamination=0.005, random_state=N
                 store_precision=True, support_fraction=None)
```

```
acc4_gauss_scaled['anomaly_gauss'] = pd.Series(model.predict(acc4_gauss_scaled
acc4_gauss['anomaly_gauss'] = acc4_gauss_scaled['anomaly_gauss']
acc4_gauss_scaled['anomaly_gauss'].value_counts()
```

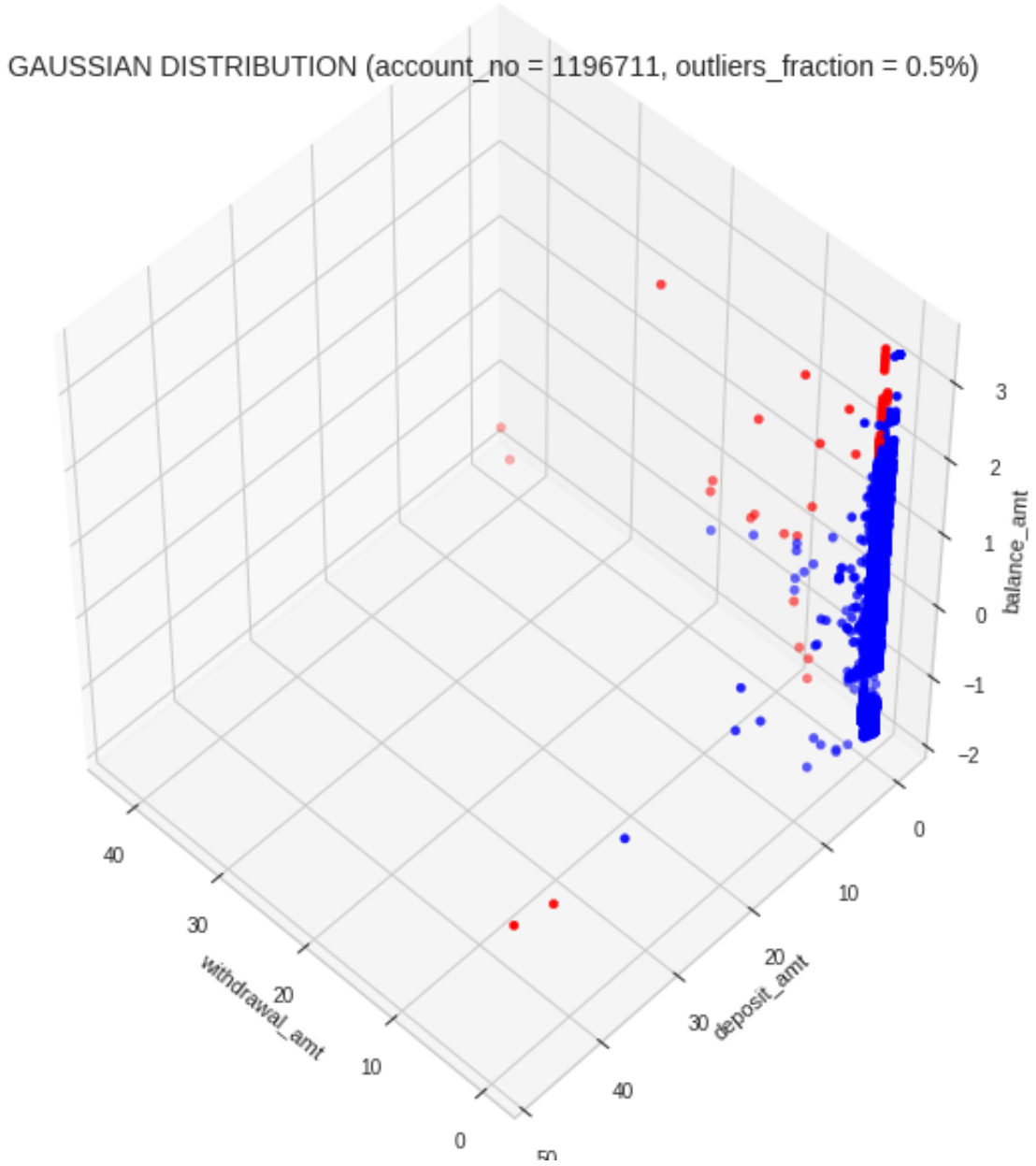
```
0    10483
1       53
Name: anomaly_gauss, dtype: int64
```

```
bank_main['gauss_4'] = 0
bank_main.loc[acc4_gauss_scaled.index,'gauss_4'] = acc4_gauss_scaled['anomaly_(
bank_main['gauss_4'].value_counts()
```

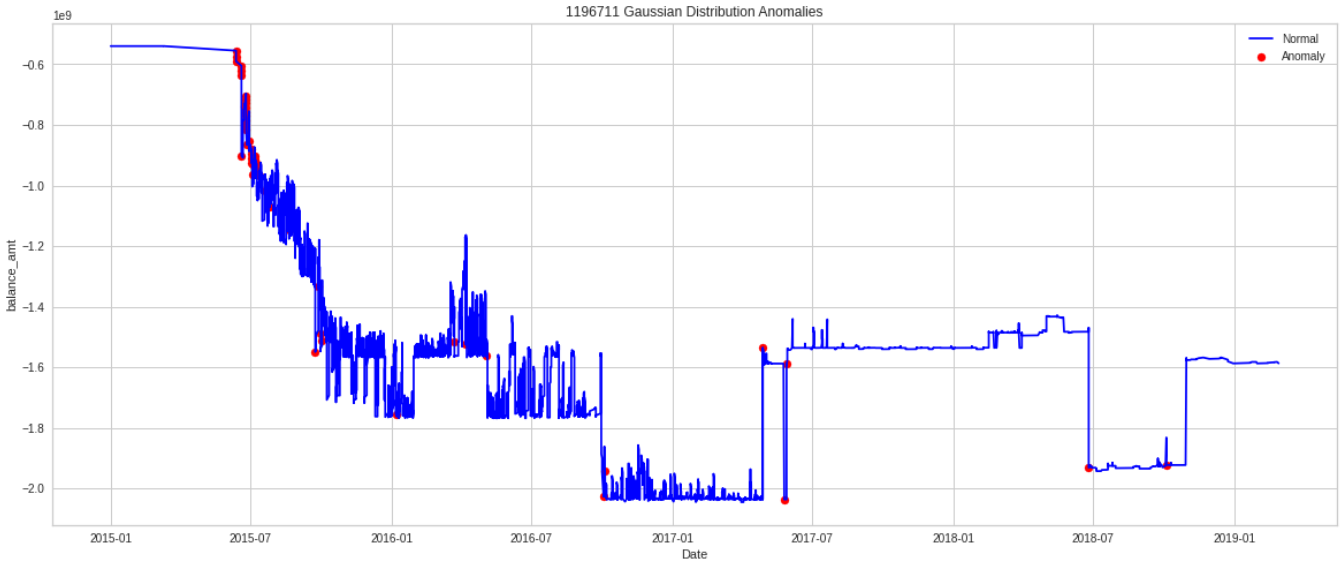
```
0    116148
1        53
Name: gauss_4, dtype: int64
```

```
labels = acc4_gauss_scaled.anomaly_gauss
colors = {0:'blue', 1:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc4_gauss_scaled.iloc[:,3], acc4_gauss_scaled.iloc[:,4], acc4_gaus
ax.set_title(f'GAUSSIAN DISTRIBUTION (account_no = {accounts[3]}, outliers_fra
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
df = acc4_gauss.copy()
a= df.loc[df['anomaly_gauss']==1, ['date', 'balance_amt']]
plt.figure(figsize=(20,8))
plt.plot(df['date'], df['balance_amt'], color='blue', label='Normal')
plt.scatter(a['date'], a['balance_amt'], color='red', label='Anomaly')
plt.title(f'{accounts[3]} Gaussian Distribution Anomalies')
plt.xlabel('Date')
plt.ylabel('balance_amt')
plt.legend()
plt.show()
```



(V) Gaussian Distribution account_no: 409000493210

```
acc5_gauss = acc5.copy()
scaler = StandardScaler()
acc5_gauss_scaled = pd.DataFrame(scaler.fit_transform(acc5_gauss[acc5.columns[2
acc5_gauss_scaled.set_index(acc5_gauss.index, drop=True, inplace=True)
acc5_gauss_scaled.head(3)
```

	day_diff	weekend_date	weekend_value_date	withdrawal_amt	deposit_am
7578	0.0	-0.249713	-0.249713	-0.042609	1.20359
7579	0.0	-0.249713	-0.249713	-0.042227	-0.04235
7580	0.0	-0.249713	-0.249713	-0.042555	-0.04235

```
outliers_fraction = .005
model = EllipticEnvelope(contamination=outliers_fraction)
model.fit(acc5_gauss_scaled)
```

```
EllipticEnvelope(assume_centered=False, contamination=0.005, random_state=N
                 store_precision=True, support_fraction=None)
```

```
acc5_gauss_scaled['anomaly_gauss'] = pd.Series(model.predict(acc5_gauss_scaled
acc5_gauss['anomaly_gauss'] = acc5_gauss_scaled['anomaly_gauss']
acc5_gauss_scaled['anomaly_gauss'].value_counts()
```

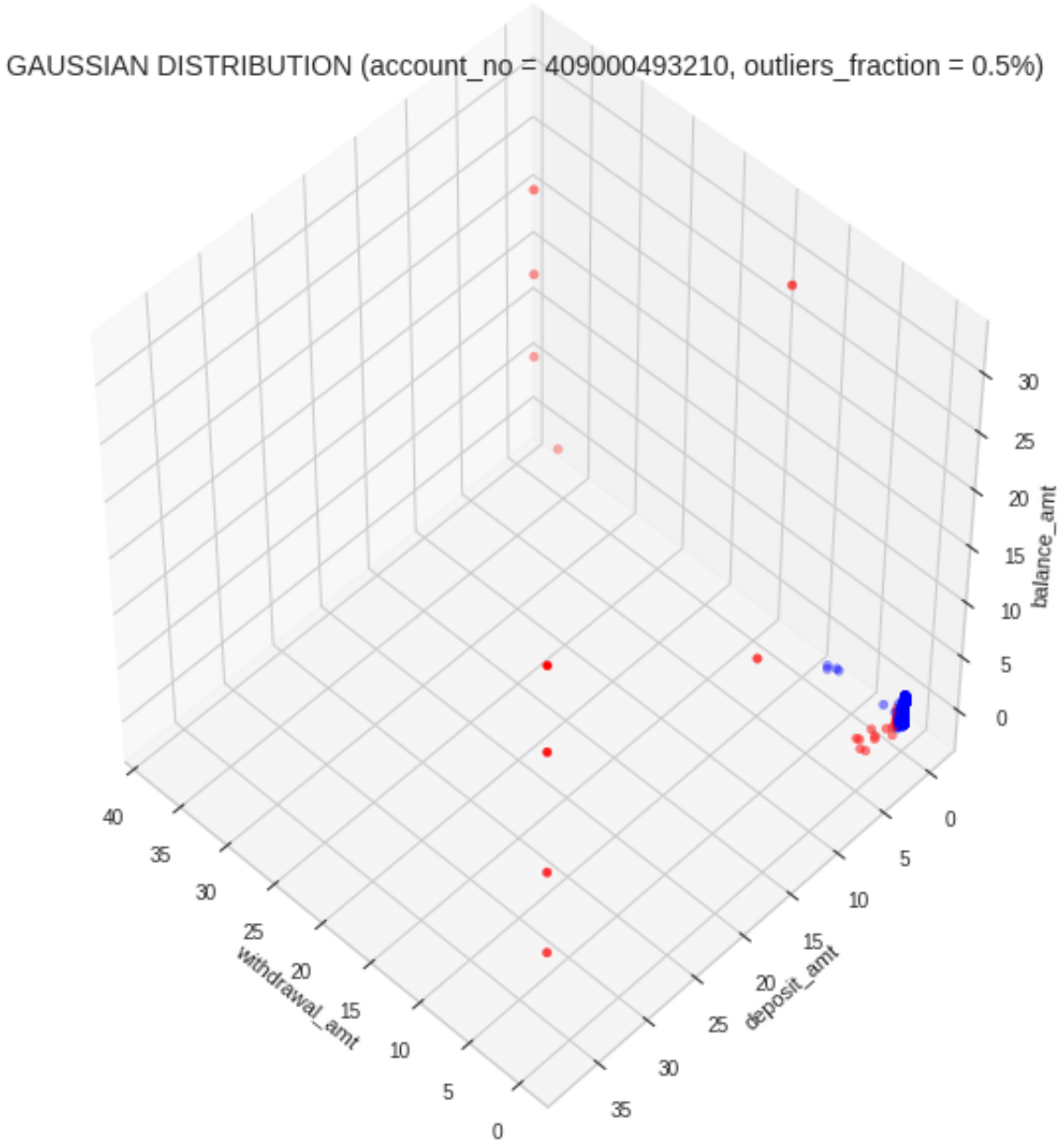
```
0    5983
1      31
Name: anomaly_gauss, dtype: int64
```

```
bank_main['gauss_5'] = 0
bank_main.loc[acc5_gauss_scaled.index,'gauss_5'] = acc5_gauss_scaled['anomaly_
bank_main['gauss_5'].value_counts()
```

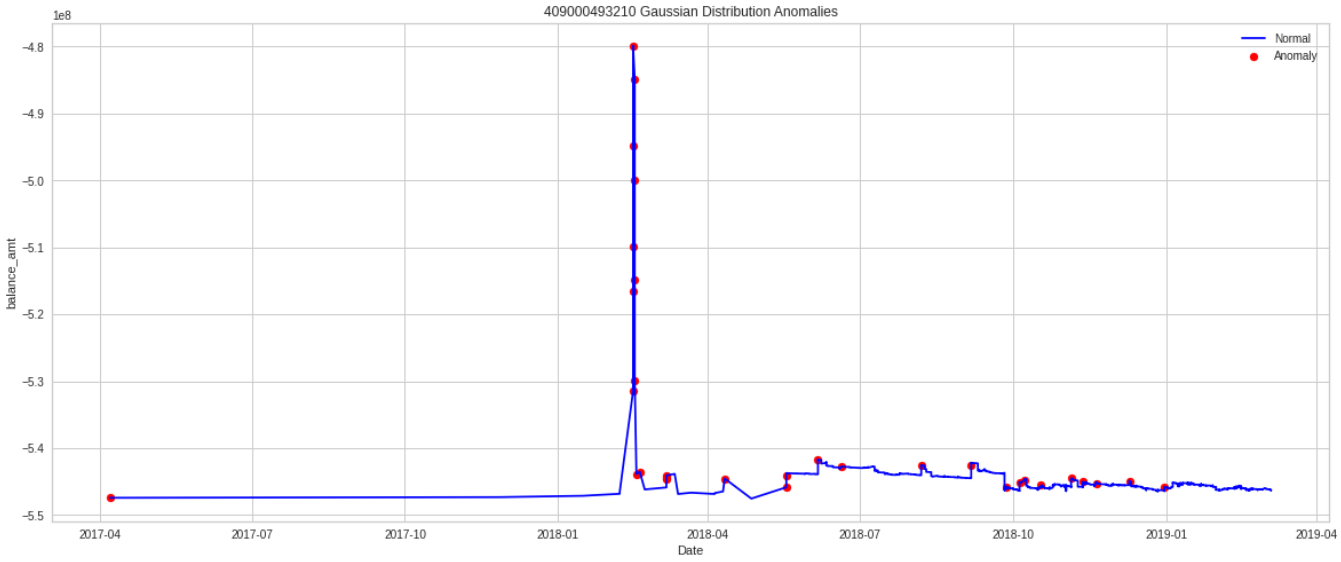
```
0    116170
1        31
Name: gauss_5, dtype: int64
```

```
labels = acc5_gauss_scaled.anomaly_gauss
colors = {0:'blue', 1:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc5_gauss_scaled.iloc[:,3], acc5_gauss_scaled.iloc[:,4], acc5_gaus
ax.set_title(f'GAUSSIAN DISTRIBUTION (account_no = {accounts[4]}, outliers_fra
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
df = acc5_gauss.copy()
a= df.loc[df['anomaly_gauss']==1, ['date', 'balance_amt']]
plt.figure(figsize=(20,8))
plt.plot(df['date'], df['balance_amt'], color='blue', label='Normal')
plt.scatter(a['date'], a['balance_amt'], color='red', label='Anomaly')
plt.title(f'{accounts[4]} Gaussian Distribution Anomalies')
plt.xlabel('Date')
plt.ylabel('balance_amt')
plt.legend()
plt.show()
```



(VI) Gaussian Distribution account_no: 409000438611

```
acc6_gauss = acc6.copy()
scaler = StandardScaler()
acc6_gauss_scaled = pd.DataFrame(scaler.fit_transform(acc6_gauss[acc6.columns[2
acc6_gauss_scaled.set_index(acc6_gauss.index, drop=True, inplace=True)
acc6_gauss_scaled.head(3)
```

	day_diff	weekend_date	weekend_value_date	withdrawal_amt	deposit_am
2990	0.0	-0.280204	-0.280204	-0.217132	52.87383
2991	0.0	-0.280204	-0.280204	27.304861	-0.32047
2992	0.0	-0.280204	-0.280204	8.251173	-0.32047

```
outliers_fraction = .005
model = EllipticEnvelope(contamination=outliers_fraction)
model.fit(acc6_gauss_scaled)
```

```
EllipticEnvelope(assume_centered=False, contamination=0.005, random_state=N
                 store_precision=True, support_fraction=None)
```

```
acc6_gauss_scaled['anomaly_gauss'] = pd.Series(model.predict(acc6_gauss_scaled
acc6_gauss['anomaly_gauss'] = acc6_gauss_scaled['anomaly_gauss']
acc6_gauss_scaled['anomaly_gauss'].value_counts()
```

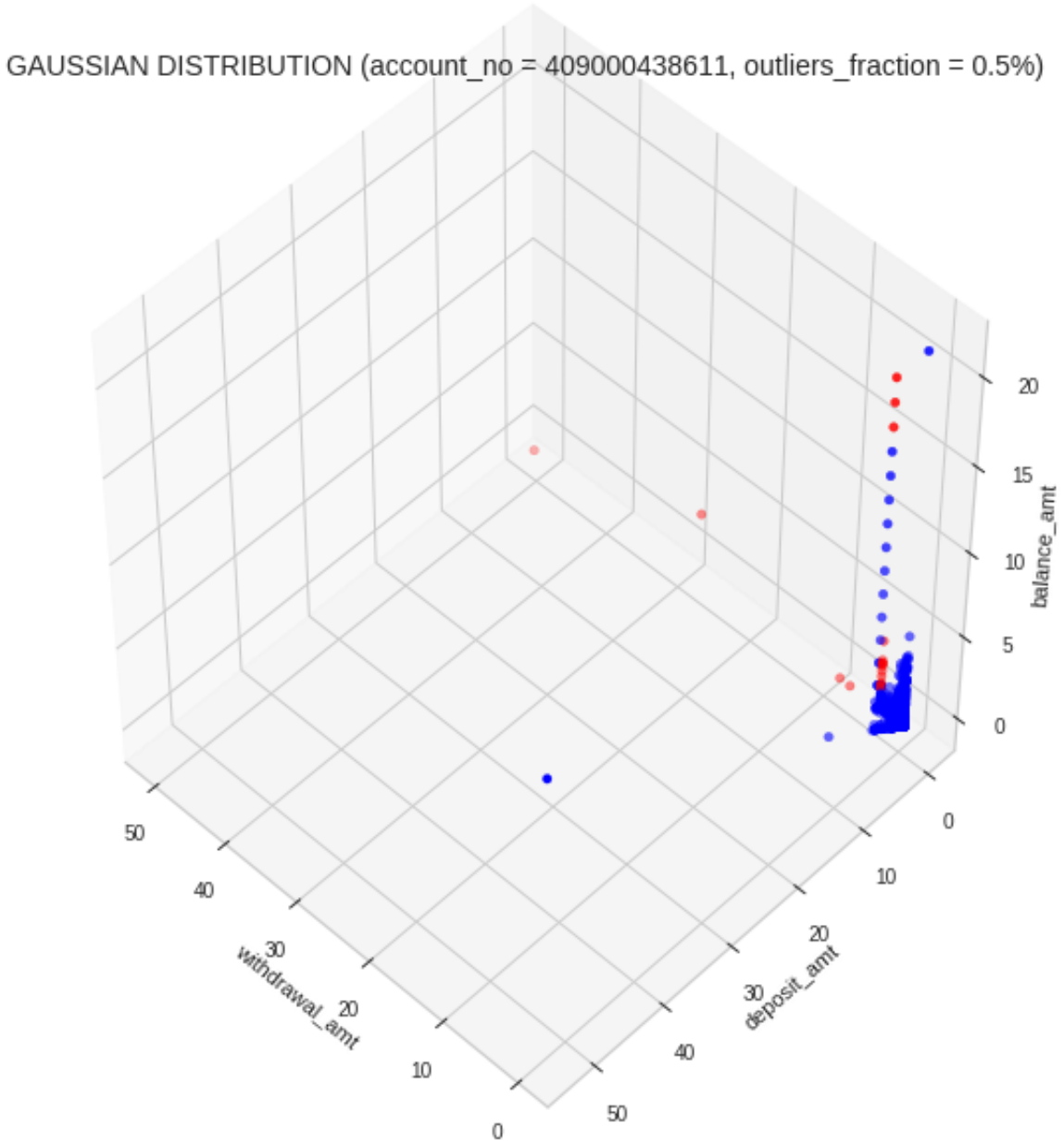
```
0    4565
1      23
Name: anomaly_gauss, dtype: int64
```

```
bank_main['gauss_6'] = 0
bank_main.loc[acc6_gauss_scaled.index,'gauss_6'] = acc6_gauss_scaled['anomaly_
bank_main['gauss_6'].value_counts()
```

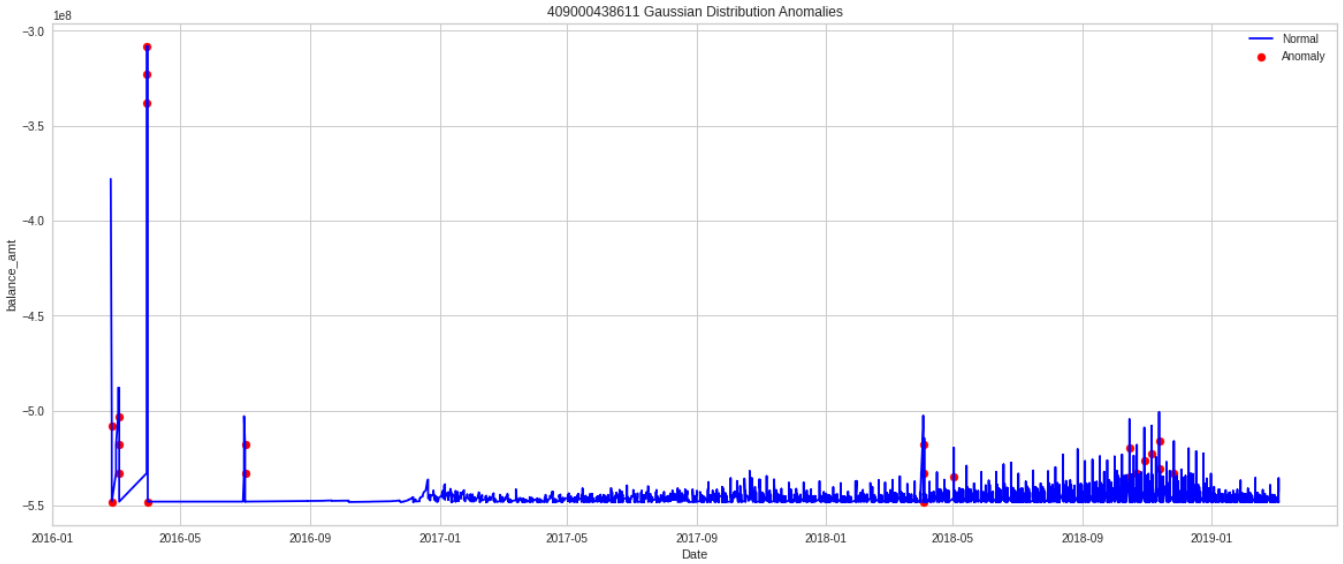
```
0    116178
1        23
Name: gauss_6, dtype: int64
```

```
labels = acc6_gauss_scaled.anomaly_gauss
colors = {0:'blue', 1:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc6_gauss_scaled.iloc[:,3], acc6_gauss_scaled.iloc[:,4], acc6_gaus
ax.set_title(f'GAUSSIAN DISTRIBUTION (account_no = {accounts[5]}, outliers_fra
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
df = acc6_gauss.copy()
a= df.loc[df['anomaly_gauss']==1, ['date', 'balance_amt']]
plt.figure(figsize=(20,8))
plt.plot(df['date'], df['balance_amt'], color='blue', label='Normal')
plt.scatter(a['date'], a['balance_amt'], color='red', label='Anomaly')
plt.title(f'{accounts[5]} Gaussian Distribution Anomalies')
plt.xlabel('Date')
plt.ylabel('balance_amt')
plt.legend()
plt.show()
```



(VII) Gaussian Distribution account_no: 409000611074

```
acc7_gauss = acc7.copy()
scaler = StandardScaler()
acc7_gauss_scaled = pd.DataFrame(scaler.fit_transform(acc7_gauss[acc7.columns[2
acc7_gauss_scaled.set_index(acc7_gauss.index, drop=True, inplace=True)
acc7_gauss_scaled.head(3)
```

	day_diff	weekend_date	weekend_value_date	withdrawal_amt	deposit_amt	l
0	0.0	-0.269481	-0.269481	-0.687913	3.664767	
1	0.0	-0.269481	-0.269481	-0.687913	3.664767	
2	0.0	-0.269481	-0.269481	-0.687913	1.550196	

```
outliers_fraction = .01
model = EllipticEnvelope(contamination=outliers_fraction)
model.fit(acc7_gauss_scaled)
```

```
EllipticEnvelope(assume_centered=False, contamination=0.01, random_state=No
                 store_precision=True, support_fraction=None)
```

```
acc7_gauss_scaled['anomaly_gauss'] = pd.Series(model.predict(acc7_gauss_scaled
acc7_gauss['anomaly_gauss'] = acc7_gauss_scaled['anomaly_gauss']
acc7_gauss_scaled['anomaly_gauss'].value_counts()
```

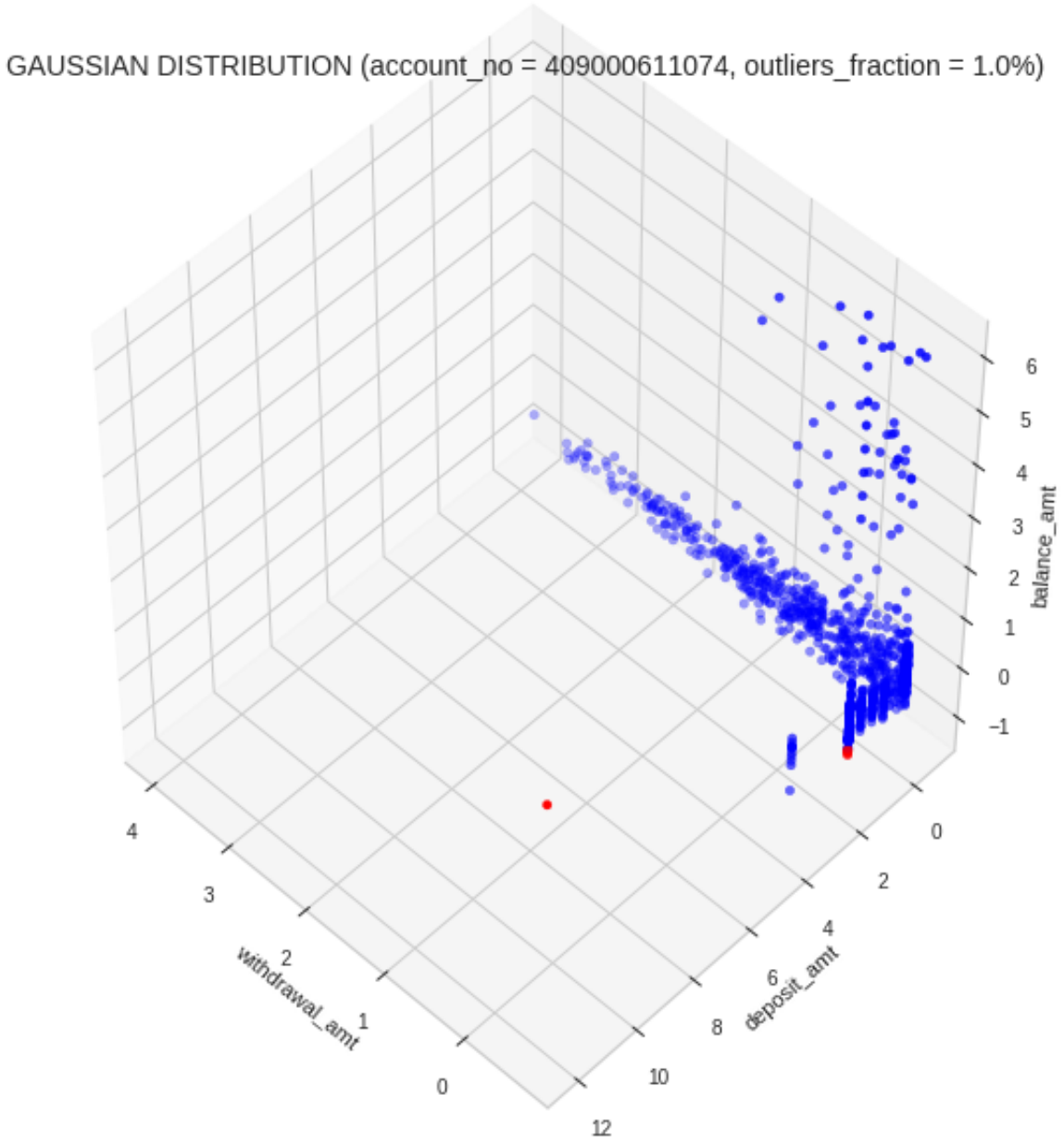
```
0    1082
1      11
Name: anomaly_gauss, dtype: int64
```

```
bank_main['gauss_7'] = 0
bank_main.loc[acc7_gauss_scaled.index,'gauss_7'] = acc7_gauss_scaled['anomaly_
bank_main['gauss_7'].value_counts()
```

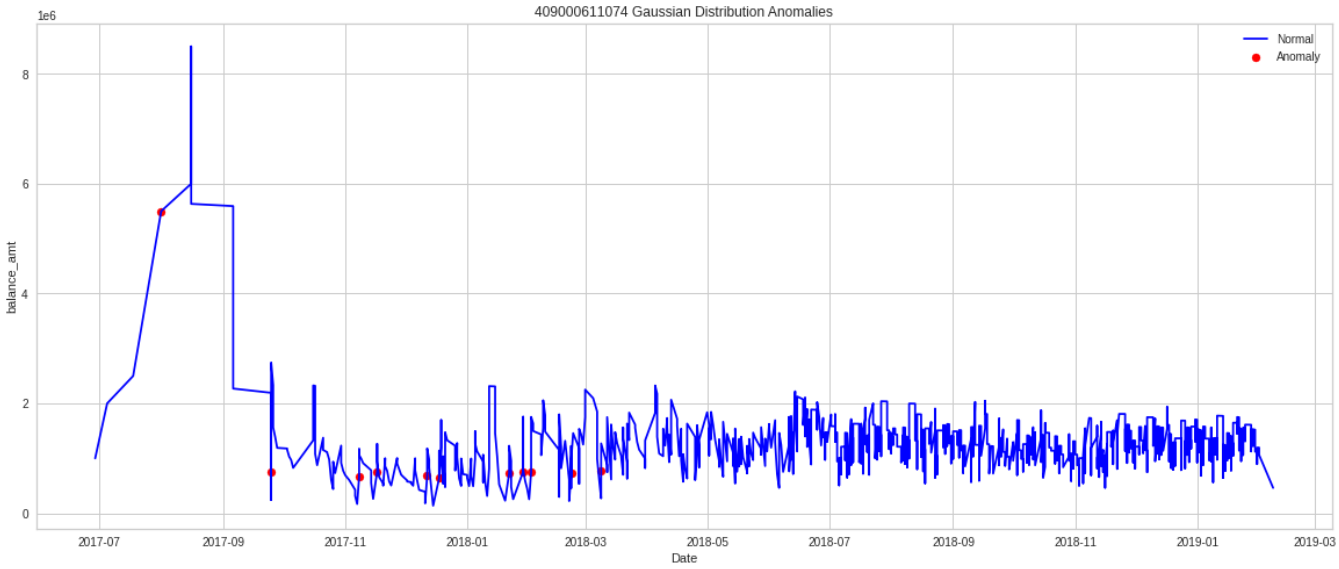
```
0    116190
1        11
Name: gauss_7, dtype: int64
```

```
labels = acc7_gauss_scaled.anomaly_gauss
colors = {0:'blue', 1:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc7_gauss_scaled.iloc[:,3], acc7_gauss_scaled.iloc[:,4], acc7_gaus
ax.set_title(f'GAUSSIAN DISTRIBUTION (account_no = {accounts[6]}, outliers_fra
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
df = acc7_gauss.copy()
a= df.loc[df['anomaly_gauss']==1, ['date', 'balance_amt']]
plt.figure(figsize=(20,8))
plt.plot(df['date'], df['balance_amt'], color='blue', label='Normal')
plt.scatter(a['date'], a['balance_amt'], color='red', label='Anomaly')
plt.title(f'{accounts[6]} Gaussian Distribution Anomalies')
plt.xlabel('Date')
plt.ylabel('balance_amt')
plt.legend()
plt.show()
```



(VIII) Gaussian Distribution account_no: 409000493201

```
acc8_gauss = acc8.copy()
scaler = StandardScaler()
acc8_gauss_scaled = pd.DataFrame(scaler.fit_transform(acc8_gauss[acc5.columns[2
acc8_gauss_scaled.set_index(acc8_gauss.index, drop=True, inplace=True)
acc8_gauss_scaled.head(3)
```

	day_diff	weekend_date	weekend_value_date	withdrawal_amt	deposit_am
1093	0.0	-0.261873	-0.261873	-0.450731	3.00717
1094	0.0	-0.261873	-0.261873	-0.446770	-0.67472
1095	0.0	-0.261873	-0.261873	-0.449547	-0.67472

```
outliers_fraction = .01
model = EllipticEnvelope(contamination=outliers_fraction)
model.fit(acc8_gauss_scaled)
```

```
EllipticEnvelope(assume_centered=False, contamination=0.01, random_state=No
                 store_precision=True, support_fraction=None)
```

```
acc8_gauss_scaled['anomaly_gauss'] = pd.Series(model.predict(acc8_gauss_scaled
acc8_gauss['anomaly_gauss'] = acc8_gauss_scaled['anomaly_gauss']
acc8_gauss_scaled['anomaly_gauss'].value_counts()
```

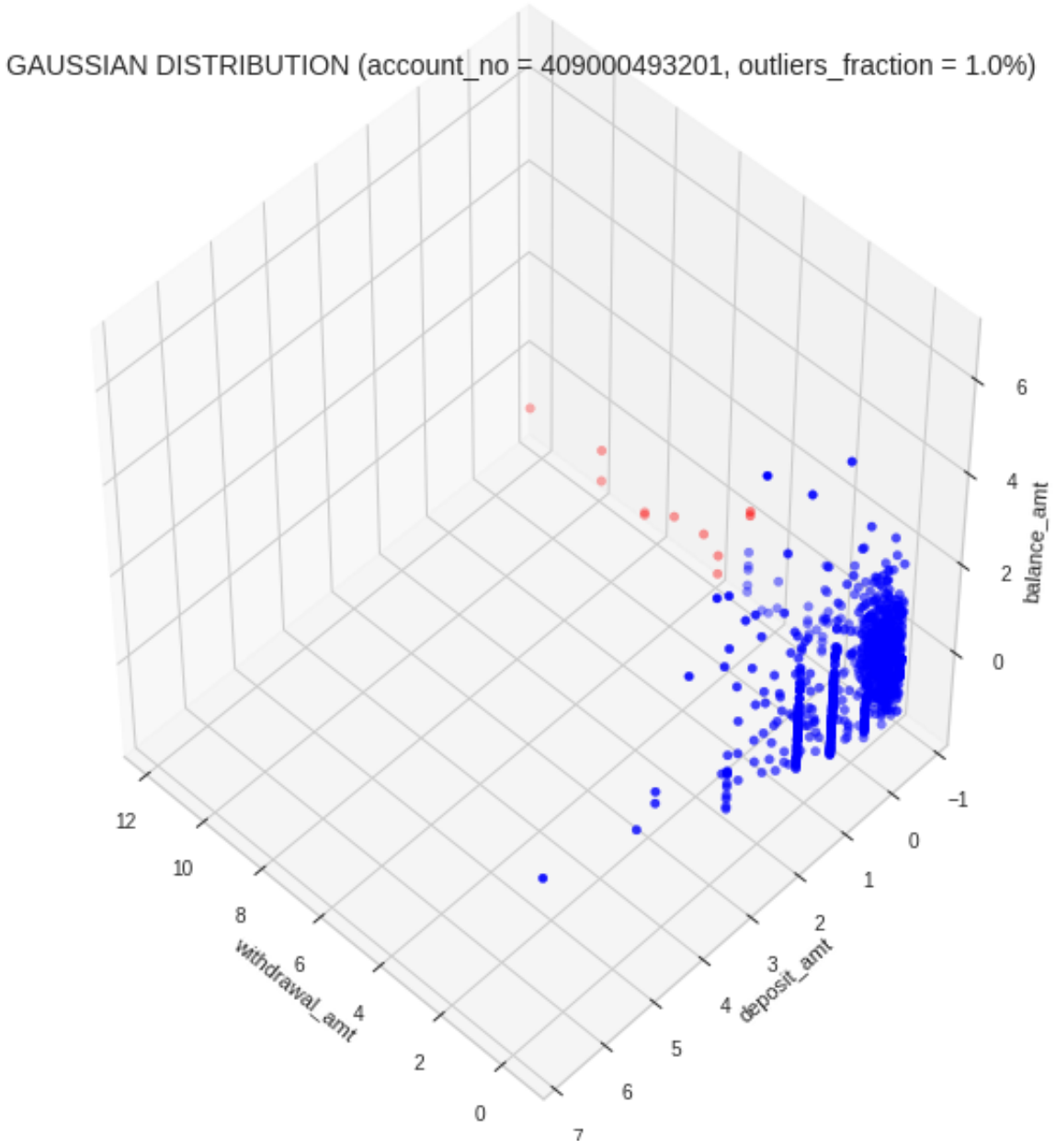
```
0    1033
1      11
Name: anomaly_gauss, dtype: int64
```

```
bank_main['gauss_8'] = 0
bank_main.loc[acc8_gauss_scaled.index,'gauss_8'] = acc8_gauss_scaled['anomaly_
bank_main['gauss_8'].value_counts()
```

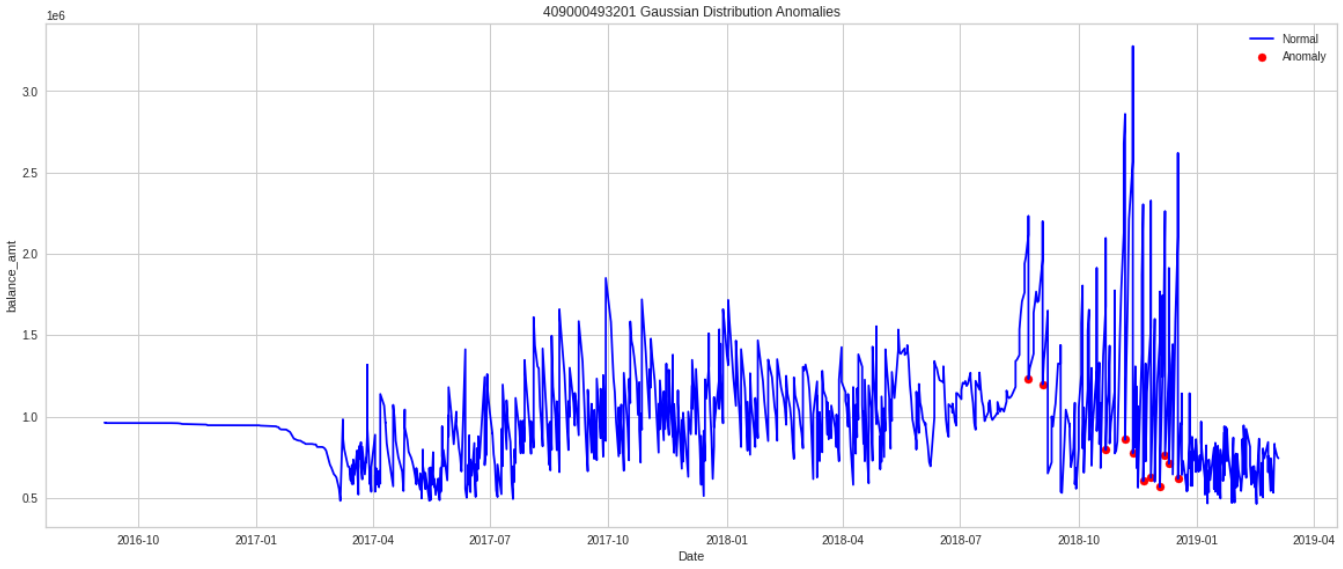
```
0    116190
1        11
Name: gauss_8, dtype: int64
```

```
labels = acc8_gauss_scaled.anomaly_gauss
colors = {0:'blue', 1:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc8_gauss_scaled.iloc[:,3], acc8_gauss_scaled.iloc[:,4], acc8_gaus
ax.set_title(f'GAUSSIAN DISTRIBUTION (account_no = {accounts[7]}, outliers_fra
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
df = acc8_gauss.copy()
a= df.loc[df['anomaly_gauss']==1, ['date', 'balance_amt']]
plt.figure(figsize=(20,8))
plt.plot(df['date'], df['balance_amt'], color='blue', label='Normal')
plt.scatter(a['date'], a['balance_amt'], color='red', label='Anomaly')
plt.title(f'{accounts[7]} Gaussian Distribution Anomalies')
plt.xlabel('Date')
plt.ylabel('balance_amt')
plt.legend()
plt.show()
```



(IX) Gaussian Distribution account_no: 409000425051

```
acc9_gauss = acc9.copy()
scaler = StandardScaler()
acc9_gauss_scaled = pd.DataFrame(scaler.fit_transform(acc9_gauss[acc9.columns[2
acc9_gauss_scaled.set_index(acc9_gauss.index, drop=True, inplace=True)
acc9_gauss_scaled.head(3)
```

	day_diff	weekend_date	weekend_value_date	withdrawal_amt	deposit_am
2137	0.0	-0.429695	-0.429695	-0.038344	-0.02322
2138	0.0	-0.429695	-0.429695	-0.038344	-0.05979
2139	0.0	-0.429695	-0.429695	-0.038344	-0.02322

```
outliers_fraction = .008
model = EllipticEnvelope(contamination=outliers_fraction)
model.fit(acc9_gauss_scaled)
```

```
EllipticEnvelope(assume_centered=False, contamination=0.008, random_state=N
                 store_precision=True, support_fraction=None)
```

```
acc9_gauss_scaled['anomaly_gauss'] = pd.Series(model.predict(acc9_gauss_scaled
acc9_gauss['anomaly_gauss'] = acc9_gauss_scaled['anomaly_gauss']
acc9_gauss_scaled['anomaly_gauss'].value_counts()
```

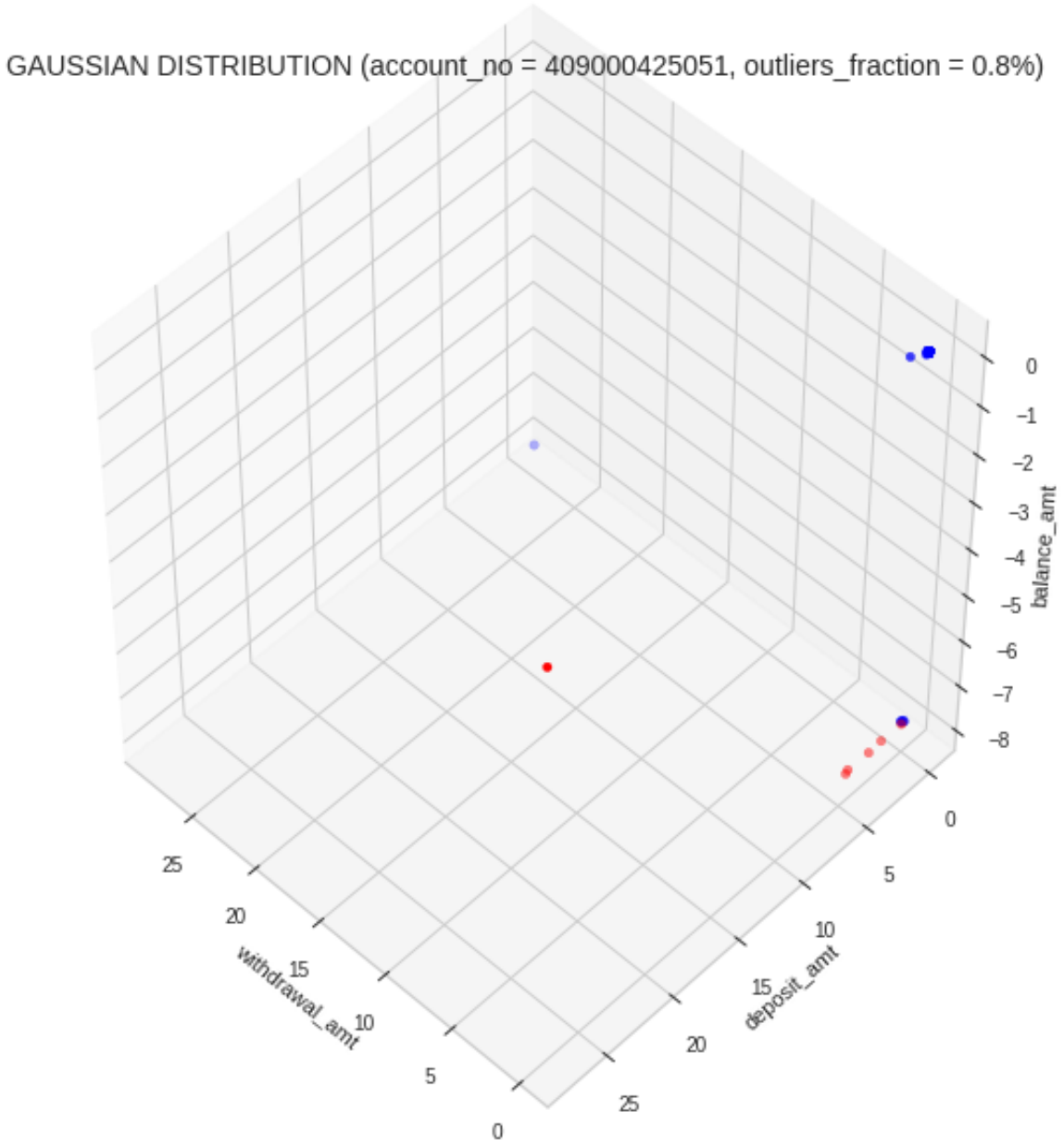
```
0    795
1      7
Name: anomaly_gauss, dtype: int64
```

```
bank_main['gauss_9'] = 0
bank_main.loc[acc9_gauss_scaled.index,'gauss_9'] = acc9_gauss_scaled['anomaly_
bank_main['gauss_9'].value_counts()
```

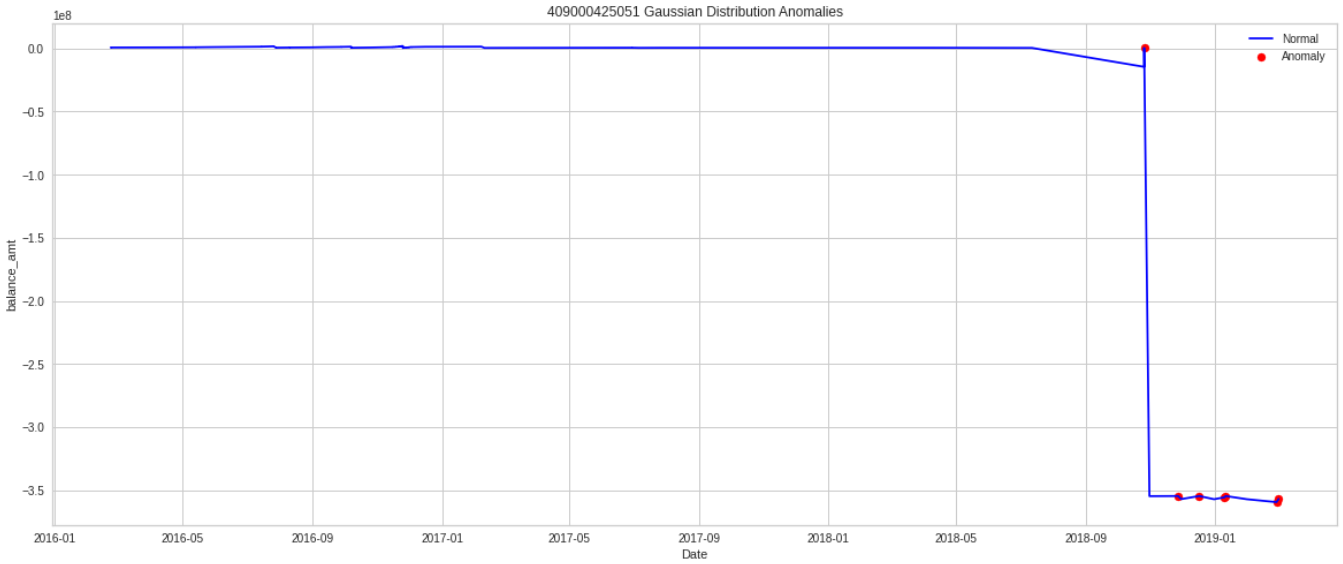
```
0    116194
1         7
Name: gauss_9, dtype: int64
```

```
labels = acc9_gauss_scaled.anomaly_gauss
colors = {0:'blue', 1:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc9_gauss_scaled.iloc[:,3], acc9_gauss_scaled.iloc[:,4], acc9_gaus
ax.set_title(f'GAUSSIAN DISTRIBUTION (account_no = {accounts[8]}, outliers_fra
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
df = acc9_gauss.copy()
a= df.loc[df['anomaly_gauss']==1, ['date', 'balance_amt']]
plt.figure(figsize=(20,8))
plt.plot(df['date'], df['balance_amt'], color='blue', label='Normal')
plt.scatter(a['date'], a['balance_amt'], color='red', label='Anomaly')
plt.title(f'{accounts[8]} Gaussian Distribution Anomalies')
plt.xlabel('Date')
plt.ylabel('balance_amt')
plt.legend()
plt.show()
```



(X) Gaussian Distribution account_no: 409000405747

```
acc10_gauss = acc10.copy()
scaler = StandardScaler()
acc10_gauss_scaled = pd.DataFrame(scaler.fit_transform(acc10_gauss[acc10.column
acc10_gauss_scaled.set_index(acc10_gauss.index, drop=True, inplace=True)
acc10_gauss_scaled.head(3)
```

	day_diff	weekend_date	weekend_value_date	withdrawal_amt	deposit_am
2939	0.0	2.318405	2.318405	5.917619	-0.16033
2940	0.0	2.318405	2.318405	0.795991	-0.16033
2941	0.0	2.318405	2.318405	-0.296882	-0.16033

```
outliers_fraction = .08
model = EllipticEnvelope(contamination=outliers_fraction)
model.fit(acc10_gauss_scaled)
```

```
EllipticEnvelope(assume_centered=False, contamination=0.08, random_state=No
                 store_precision=True, support_fraction=None)
```

```
acc10_gauss_scaled['anomaly_gauss'] = pd.Series(model.predict(acc10_gauss_scal
acc10_gauss['anomaly_gauss'] = acc10_gauss_scaled['anomaly_gauss']
acc10_gauss_scaled['anomaly_gauss'].value_counts()
```

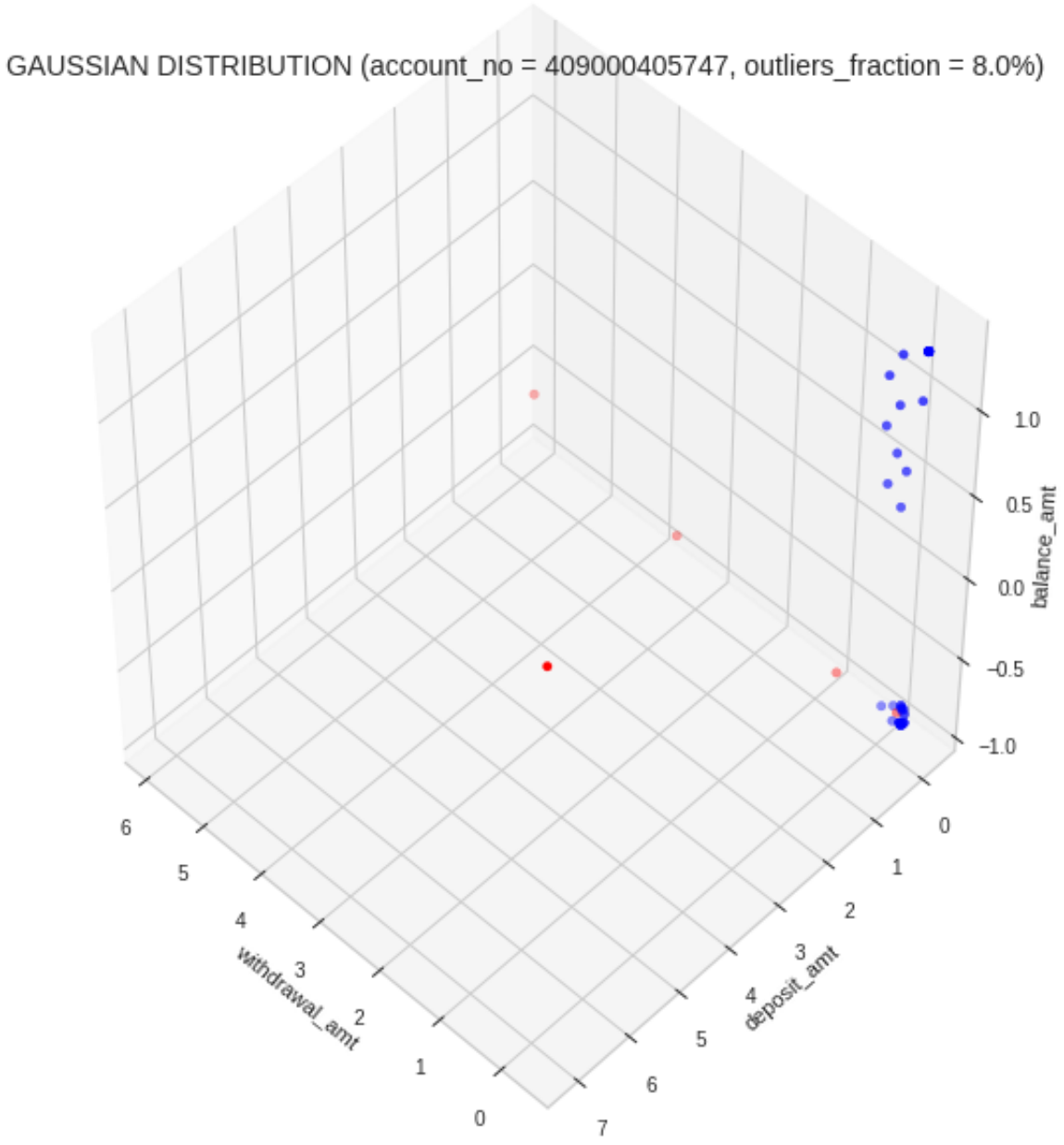
```
0    46
1     5
Name: anomaly_gauss, dtype: int64
```

```
bank_main['gauss_10'] = 0
bank_main.loc[acc10_gauss_scaled.index,'gauss_10'] = acc10_gauss_scaled['anoma
bank_main['gauss_10'].value_counts()
```

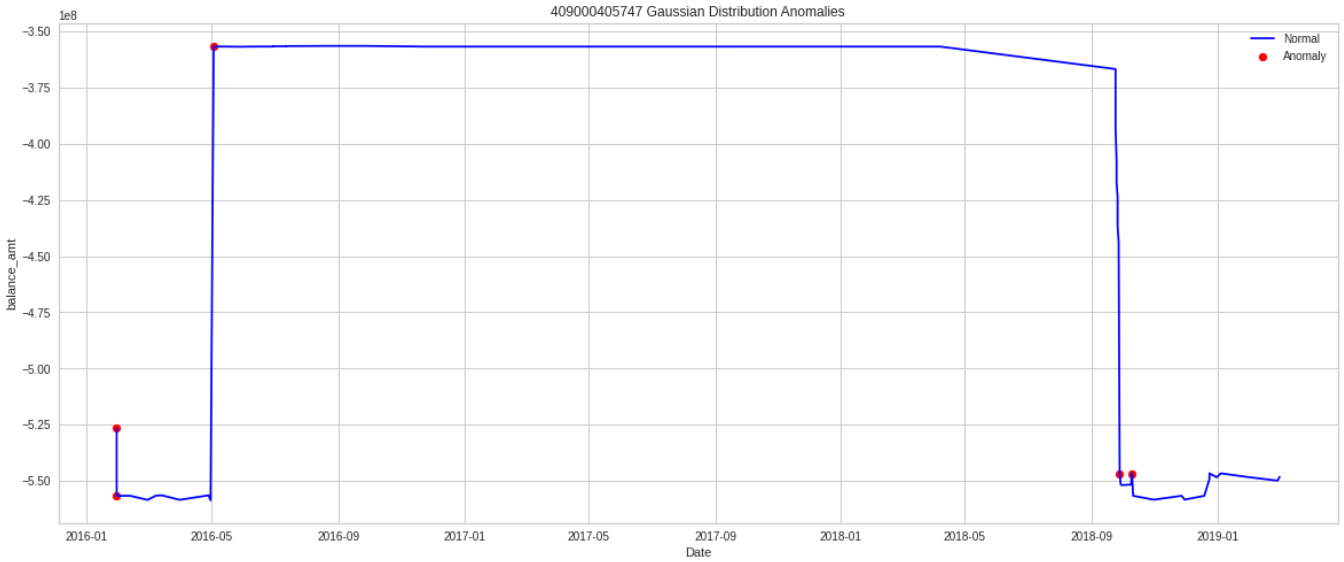
```
0    116196
1         5
Name: gauss_10, dtype: int64
```

```
labels = acc10_gauss_scaled.anomaly_gauss
colors = {0:'blue', 1:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc10_gauss_scaled.iloc[:,3], acc10_gauss_scaled.iloc[:,4], acc10_g
ax.set_title(f'GAUSSIAN DISTRIBUTION (account_no = {accounts[9]}, outliers_fra
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
df = acc10_gauss.copy()
a= df.loc[df['anomaly_gauss']==1, ['date', 'balance_amt']]
plt.figure(figsize=(20,8))
plt.plot(df['date'], df['balance_amt'], color='blue', label='Normal')
plt.scatter(a['date'], a['balance_amt'], color='red', label='Anomaly')
plt.title(f'{accounts[9]} Gaussian Distribution Anomalies')
plt.xlabel('Date')
plt.ylabel('balance_amt')
plt.legend()
plt.show()
```




```
bank_main['accounts_gaussian_distribution'] = bank_main.gauss_1 + bank_main.ga
```

```
bank_main['accounts_gaussian_distribution'].value_counts()
```

```
0    115598
1       603
Name: accounts_gaussian_distribution, dtype: int64
```

iv. KMeans Clustering Anomaly Detection

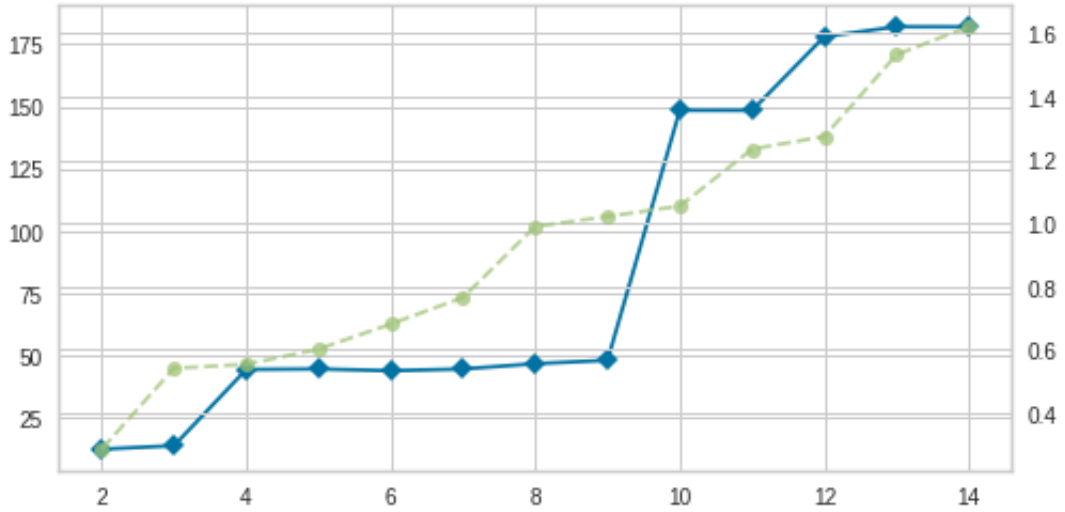
(I) Customer account_no_1196428

```
acc1_kmeans = acc1.copy()
scaler = StandardScaler()
acc1_kmeans_scaled = pd.DataFrame(scaler.fit_transform(acc1_kmeans[acc1.columns
acc1_kmeans_scaled.set_index(acc1_kmeans.index, drop=True, inplace=True)
acc1_kmeans_scaled.head(3)
```

	day_diff	weekend_date	weekend_value_date	withdrawal_amt	deposit_ar
37582	-0.009703	-0.327498	-0.327574	-0.363895	-0.0352
37583	-0.009703	-0.327498	-0.327574	-0.363895	-0.1051
37584	-0.009703	-0.327498	-0.327574	-0.363895	-0.2422

```
# Instantiate the clustering model and visualizer
visualizer = KElbowVisualizer(KMeans(), k=(2,15))
plt.figure(figsize=(8,4)).patch.set_facecolor('xkcd:white')
visualizer.fit(acc1_kmeans_scaled)       # Fit the data to the visualizer
# visualizer.show()        # Finalize and render the figure
```

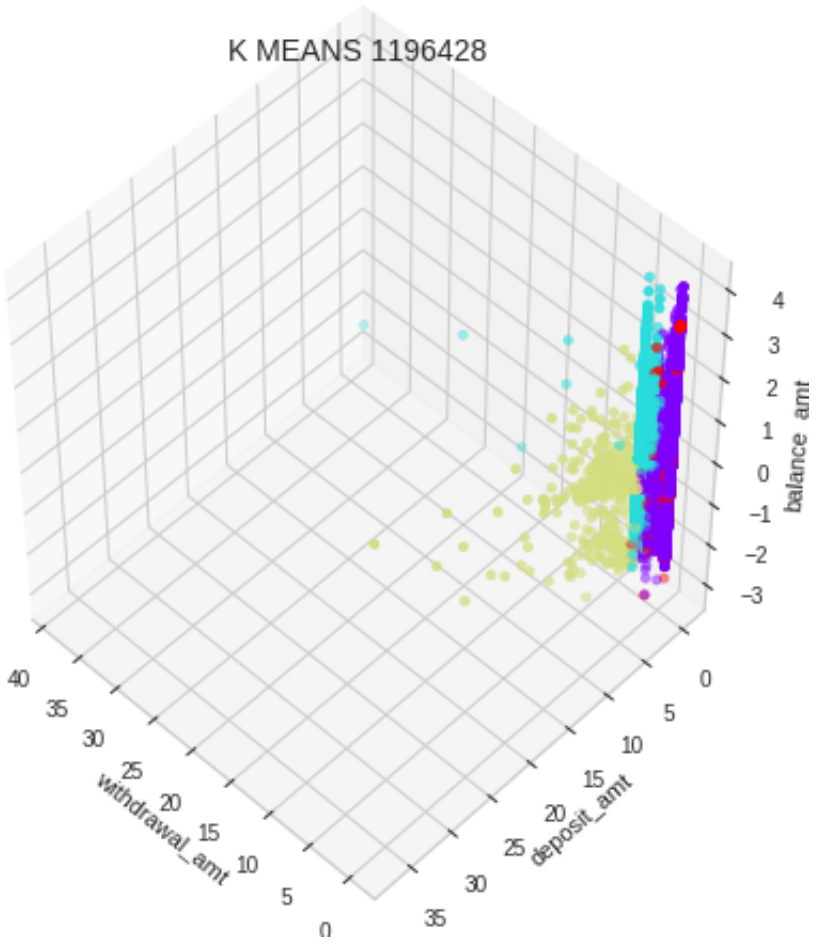
```
KElbowVisualizer(ax=<matplotlib.axes._subplots.AxesSubplot object at 0x7fa4
                 k=None, metric=None, model=None, timings=True)
```



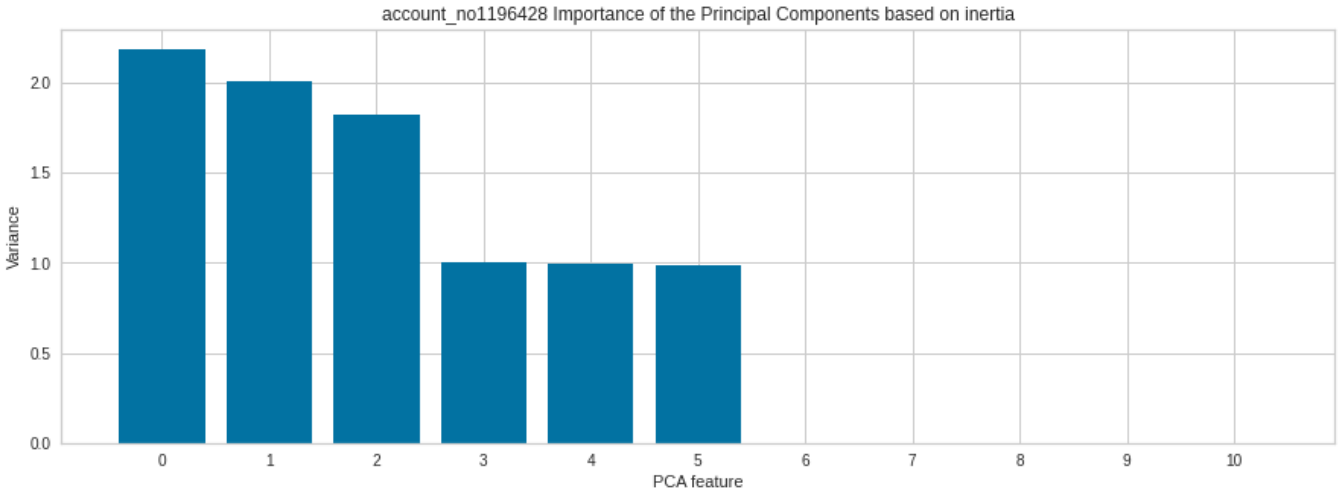
```
kmeans = KMeans(n_clusters=4)
kmeans.fit(acc1_kmeans_scaled)
labels = kmeans.labels_
```

```
fig = plt.figure(1, figsize=(6,6))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc1_kmeans_scaled.iloc[:,3], acc1_kmeans_scaled.iloc[:,4], acc1_km
ax.set_title(f'K MEANS {accounts[0]}', fontsize=14)
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
x = acc1_kmeans_scaled
pca = PCA()
pipeline = make_pipeline(pca)
pipeline.fit(x)
# Plot the principal components against their inertia
features = range(pca.n_components_)
_ = plt.figure(figsize=(15, 5))
_ = plt.bar(features, pca.explained_variance_)
_ = plt.xlabel('PCA feature')
_ = plt.ylabel('Variance')
_ = plt.xticks(features)
_ = plt.title(f"account_no{accounts[0]} Importance of the Principal Components
plt.show()
```




```
acc1_pca = pd.DataFrame(PCA(n_components=5).fit_transform(acc1_kmeans_scaled),
```

```
kmeans = KMeans(n_clusters=4)
kmeans.fit(acc1_pca)
labels = kmeans.predict(acc1_pca)
unique_elements, counts_elements = np.unique(labels, return_counts=True)
clusters = np.asarray((unique_elements, counts_elements))

# Assume that 0.5% of the entire data set are anomalies
outliers_fraction = 0.003
# get the distance between each point and its nearest centroid. The biggest di
distance = getDistanceByPoint(acc1_pca, kmeans)
# number of observations that equate to the 0.5%  of the entire data set
number_of_outliers = int(outliers_fraction*len(distance))
# Take the minimum of the largest 0.5%  of the distances as the threshold
threshold = distance.nlargest(number_of_outliers).min()
# anomaly1 contain the anomaly result of the above method Cluster (0:normal, 1
acc1_pca['anomaly_kmeans'] = (distance >= threshold).astype(int)


acc1_pca.index = acc1.index
acc1_pca.anomaly_kmeans.value_counts()
```

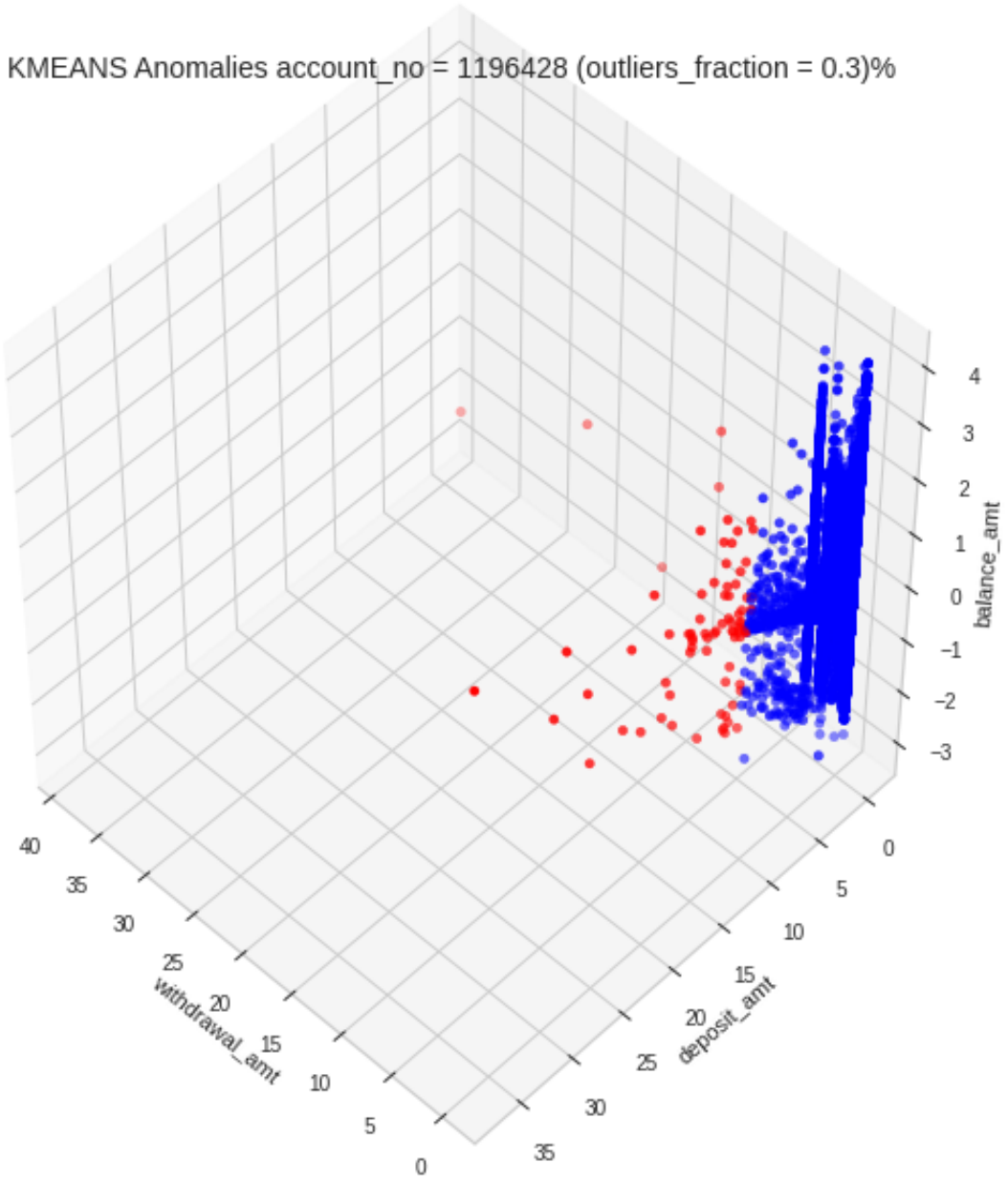
```
0    48633
1      146
Name: anomaly_kmeans, dtype: int64
```

```
acc1_kmeans_scaled['anomaly_kmeans'] = acc1_pca.anomaly_kmeans
bank_main['km_1'] = 0
bank_main.loc[acc1_kmeans_scaled.index,'km_1'] = acc1_kmeans_scaled['anomaly_k
bank_main['km_1'].value_counts()
```

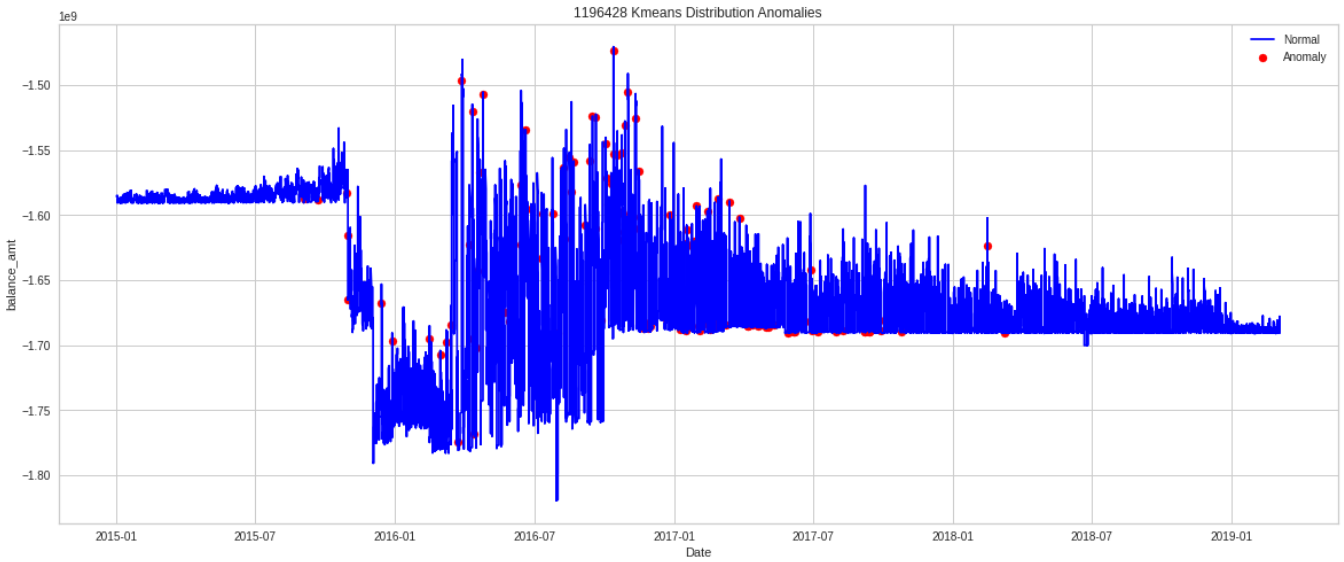
```
0    116055
1       146
Name: km_1, dtype: int64
```

```
labels = acc1_kmeans_scaled.anomaly_kmeans
colors = {0:'blue', 1:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc1_kmeans_scaled.iloc[:,3], acc1_kmeans_scaled.iloc[:,4], acc1_km
ax.set_title(f'KMEANS Anomalies account_no = {accounts[0]} (outliers_fraction =
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
acc1_kmeans['anomaly_kmeans'] = acc1_kmeans_scaled['anomaly_kmeans']
df = acc1_kmeans.copy()
a= df.loc[df['anomaly_kmeans']==1, ['date', 'balance_amt']]
plt.figure(figsize=(20,8))
plt.plot(df['date'], df['balance_amt'], color='blue', label='Normal')
plt.scatter(a['date'], a['balance_amt'], color='red', label='Anomaly')
plt.title(f'{accounts[0]} Kmeans Distribution Anomalies')
plt.xlabel('Date')
plt.ylabel('balance_amt')
plt.legend()
plt.show()
```



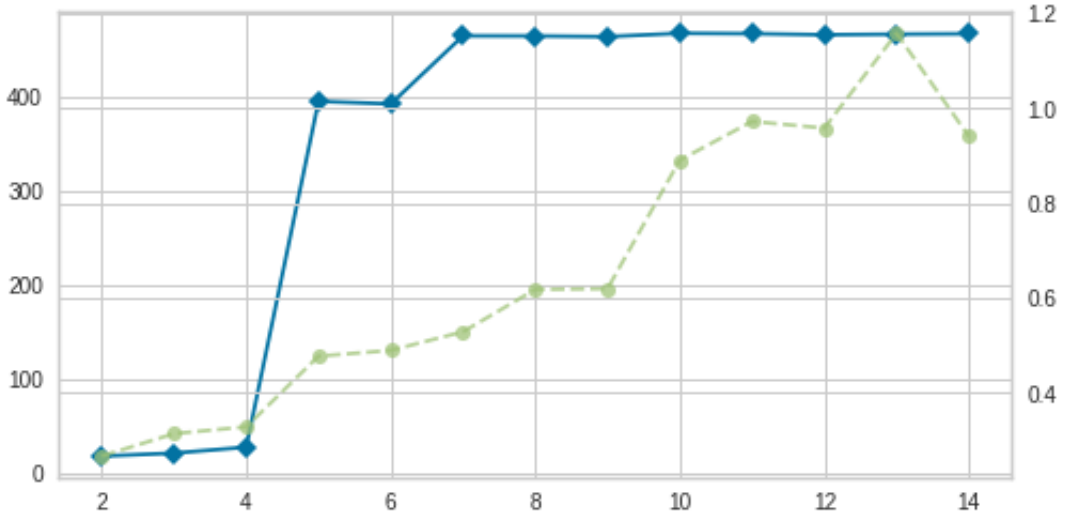
(II) Customer account_no_409000362497

```
acc2_kmeans = acc2.copy()
scaler = StandardScaler()
acc2_kmeans_scaled = pd.DataFrame(scaler.fit_transform(acc2_kmeans[acc2.columns
acc2_kmeans_scaled.set_index(acc2_kmeans.index, drop=True, inplace=True)
acc2_kmeans_scaled.head(3)
```

	day_diff	weekend_date	weekend_value_date	withdrawal_amt	deposit_ar
86361	-0.020357	-0.286669	-0.286463	-0.297246	1.00303
86362	-0.020357	-0.286669	-0.286463	-0.297246	1.00303
86363	-0.020357	-0.286669	-0.286463	-0.297246	1.00303

```
# Instantiate the clustering model and visualizer
visualizer = KElbowVisualizer(KMeans(), k=(2,15))
plt.figure(figsize=(8,4)).patch.set_facecolor('xkcd:white')
visualizer.fit(acc2_kmeans_scaled)       # Fit the data to the visualizer
# visualizer.show()        # Finalize and render the figure
```

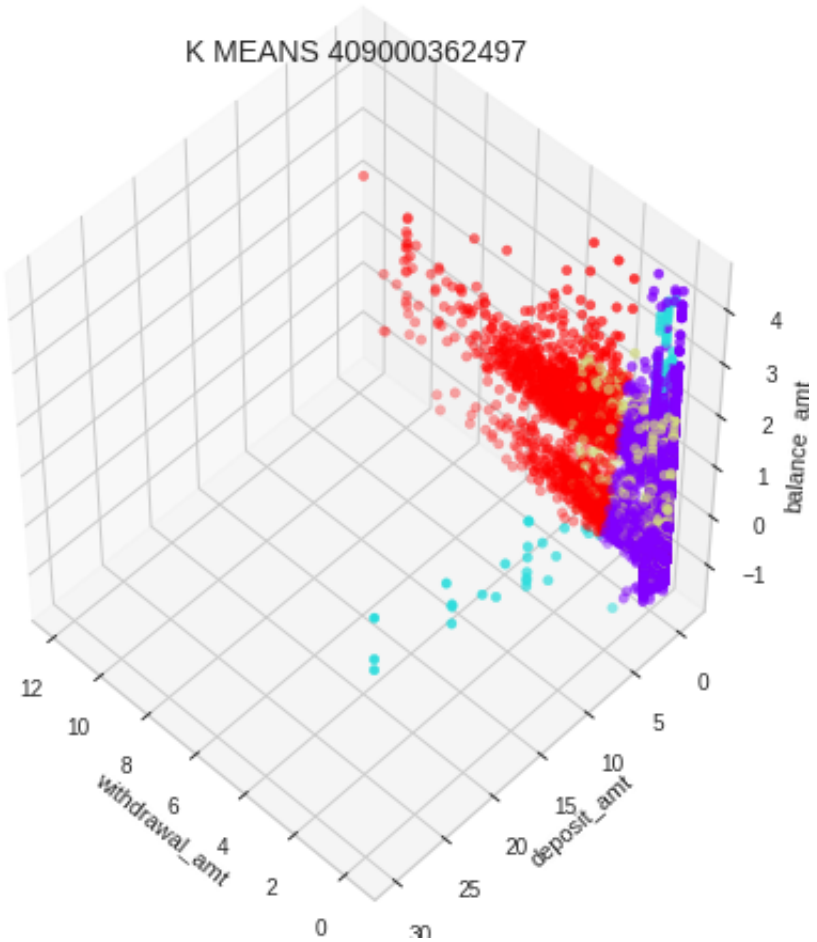
```
KElbowVisualizer(ax=<matplotlib.axes._subplots.AxesSubplot object at 0x7fa4
                 k=None, metric=None, model=None, timings=True)
```



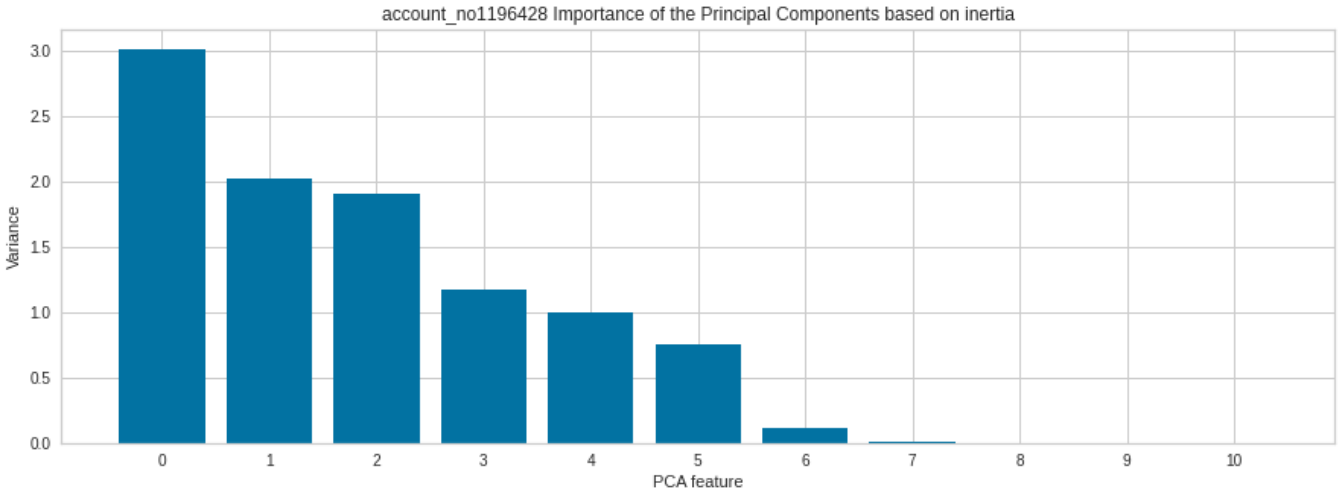

```
kmeans = KMeans(n_clusters=4)
kmeans.fit(acc2_kmeans_scaled)
labels = kmeans.labels_
```

```
fig = plt.figure(1, figsize=(6,6))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc2_kmeans_scaled.iloc[:,3], acc2_kmeans_scaled.iloc[:,4], acc2_km
ax.set_title(f'K MEANS {accounts[1]}', fontsize=14)
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
x = acc2_kmeans_scaled
pca = PCA()
pipeline = make_pipeline(pca)
pipeline.fit(x)
# Plot the principal components against their inertia
features = range(pca.n_components_)
_ = plt.figure(figsize=(15, 5))
_ = plt.bar(features, pca.explained_variance_)
_ = plt.xlabel('PCA feature')
_ = plt.ylabel('Variance')
_ = plt.xticks(features)
_ = plt.title(f"account_no{accounts[0]} Importance of the Principal Components
plt.show()
```




```
acc2_pca = pd.DataFrame(PCA(n_components=6).fit_transform(acc2_kmeans_scaled),
```

```
kmeans = KMeans(n_clusters=4)
kmeans.fit(acc2_pca)
labels = kmeans.predict(acc2_pca)
unique_elements, counts_elements = np.unique(labels, return_counts=True)
clusters = np.asarray((unique_elements, counts_elements))

outliers_fraction = 0.003
distance = getDistanceByPoint(acc2_pca, kmeans)
number_of_outliers = int(outliers_fraction*len(distance))
threshold = distance.nlargest(number_of_outliers).min()
acc2_pca['anomaly_kmeans'] = (distance >= threshold).astype(int)


acc2_pca.index = acc2.index
acc2_pca.anomaly_kmeans.value_counts()
```

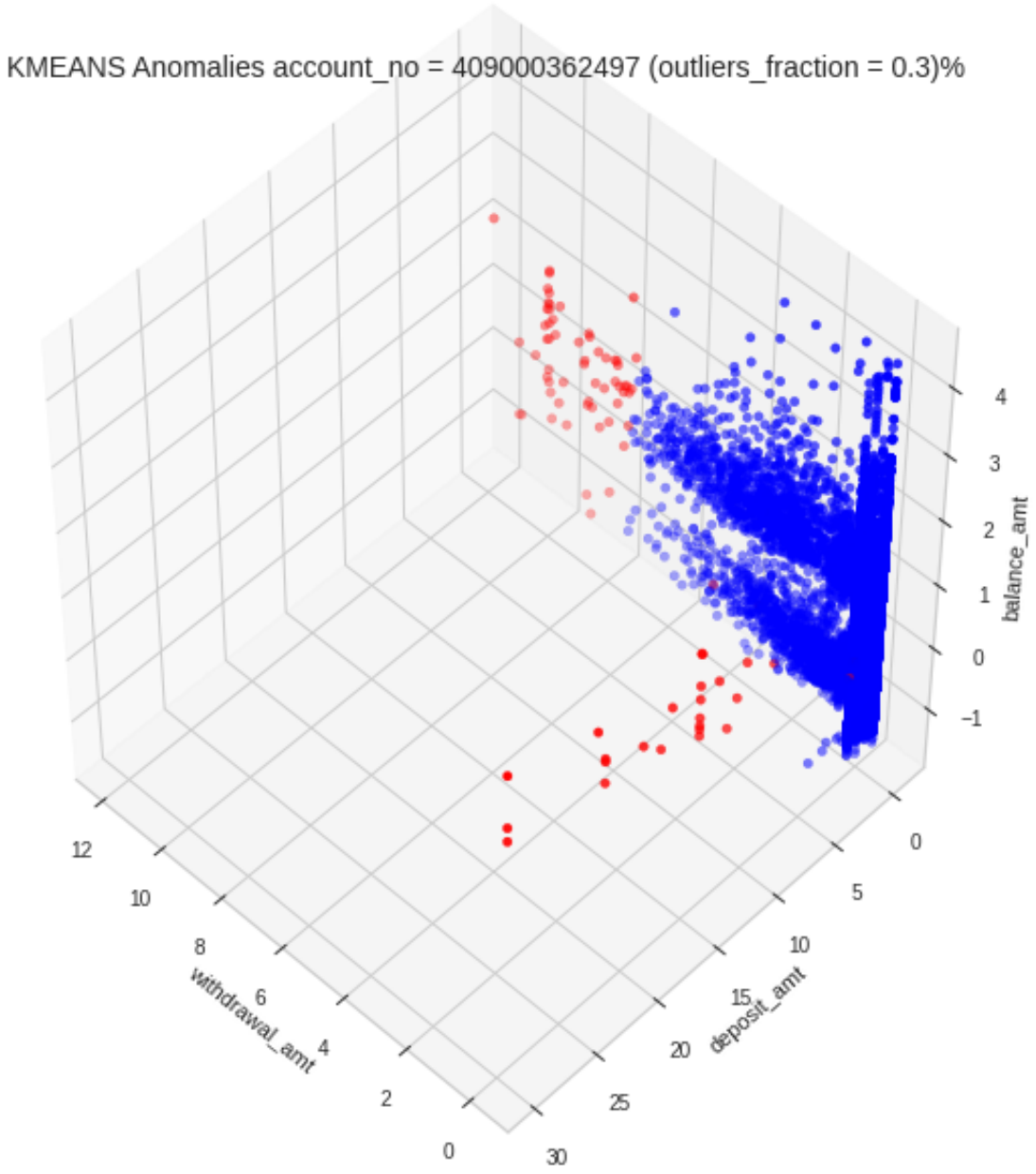
```
0    29751
1       89
Name: anomaly_kmeans, dtype: int64
```

```
acc2_kmeans_scaled['anomaly_kmeans'] = acc2_pca.anomaly_kmeans
bank_main['km_2'] = 0
bank_main.loc[acc2_kmeans_scaled.index,'km_2'] = acc2_kmeans_scaled['anomaly_k
bank_main['km_2'].value_counts()
```

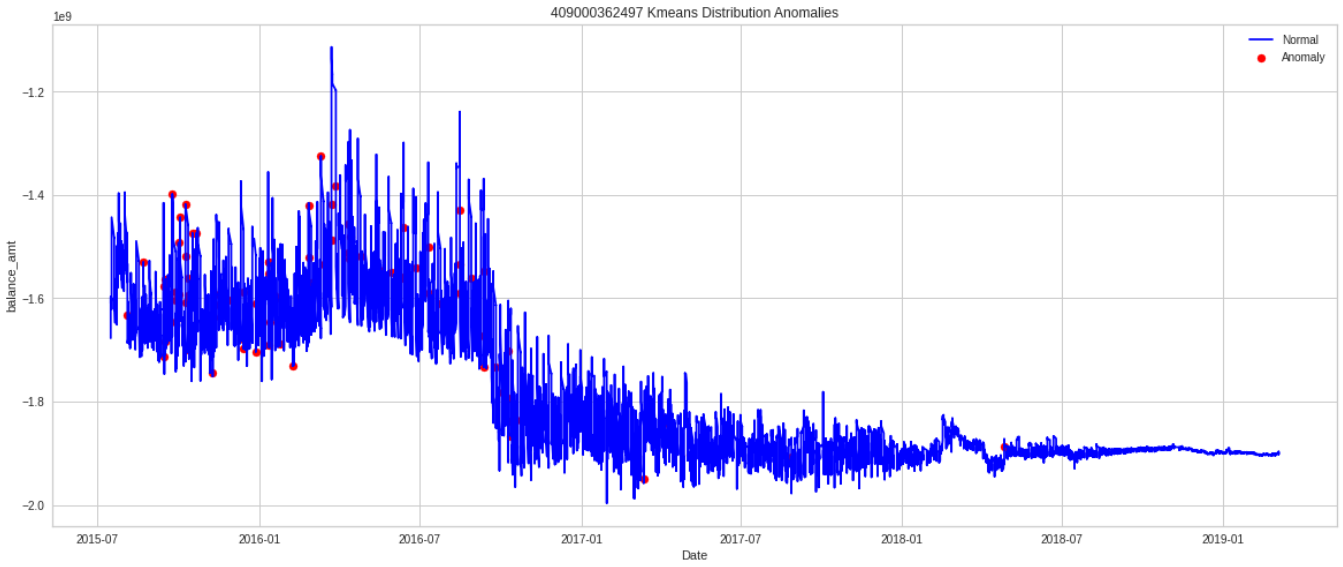
```
0    116112
1        89
Name: km_2, dtype: int64
```

```
labels = acc2_kmeans_scaled.anomaly_kmeans
colors = {0:'blue', 1:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc2_kmeans_scaled.iloc[:,3], acc2_kmeans_scaled.iloc[:,4], acc2_km
ax.set_title(f'KMEANS Anomalies account_no = {accounts[1]} (outliers_fraction =
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
acc2_kmeans['anomaly_kmeans'] = acc2_kmeans_scaled['anomaly_kmeans']
df = acc2_kmeans.copy()
a= df.loc[df['anomaly_kmeans']==1, ['date', 'balance_amt']]
plt.figure(figsize=(20,8))
plt.plot(df['date'], df['balance_amt'], color='blue', label='Normal')
plt.scatter(a['date'], a['balance_amt'], color='red', label='Anomaly')
plt.title(f'{accounts[1]} Kmeans Distribution Anomalies')
plt.xlabel('Date')
plt.ylabel('balance_amt')
plt.legend()
plt.show()
```




```
accounts[2]
```

```
'409000438620'
```

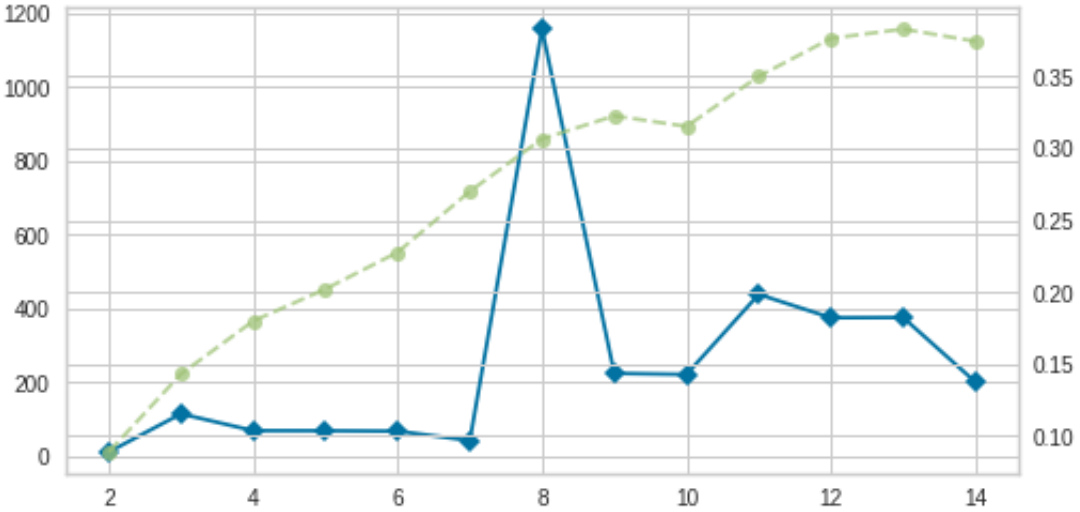
(III) Customer account_no_409000438620

```
acc3_kmeans = acc3.copy()
scaler = StandardScaler()
acc3_kmeans_scaled = pd.DataFrame(scaler.fit_transform(acc3_kmeans[acc3.columns
acc3_kmeans_scaled.set_index(acc3_kmeans.index, drop=True, inplace=True)
acc3_kmeans_scaled.head(3)
```

	day_diff	weekend_date	weekend_value_date	withdrawal_amt	deposit_ar
13592	0.0	-0.310493	-0.310493	-0.199596	68.5563
13593	0.0	-0.310493	-0.310493	15.416558	-0.1612
13594	0.0	-0.310493	-0.310493	-0.199596	1.7307

```
# Instantiate the clustering model and visualizer
visualizer = KElbowVisualizer(KMeans(), k=(2,15))
plt.figure(figsize=(8,4)).patch.set_facecolor('xkcd:white')
visualizer.fit(acc3_kmeans_scaled)       # Fit the data to the visualizer
# visualizer.show()        # Finalize and render the figure
```

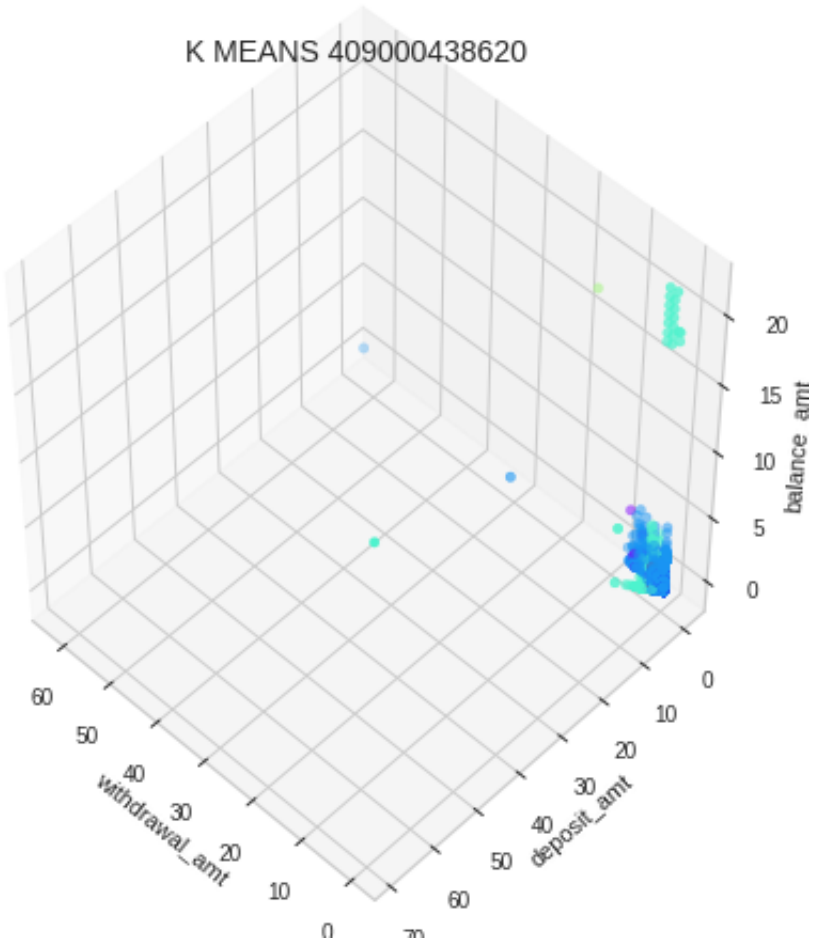
```
KElbowVisualizer(ax=<matplotlib.axes._subplots.AxesSubplot object at 0x7fa4
                 k=None, metric=None, model=None, timings=True)
```



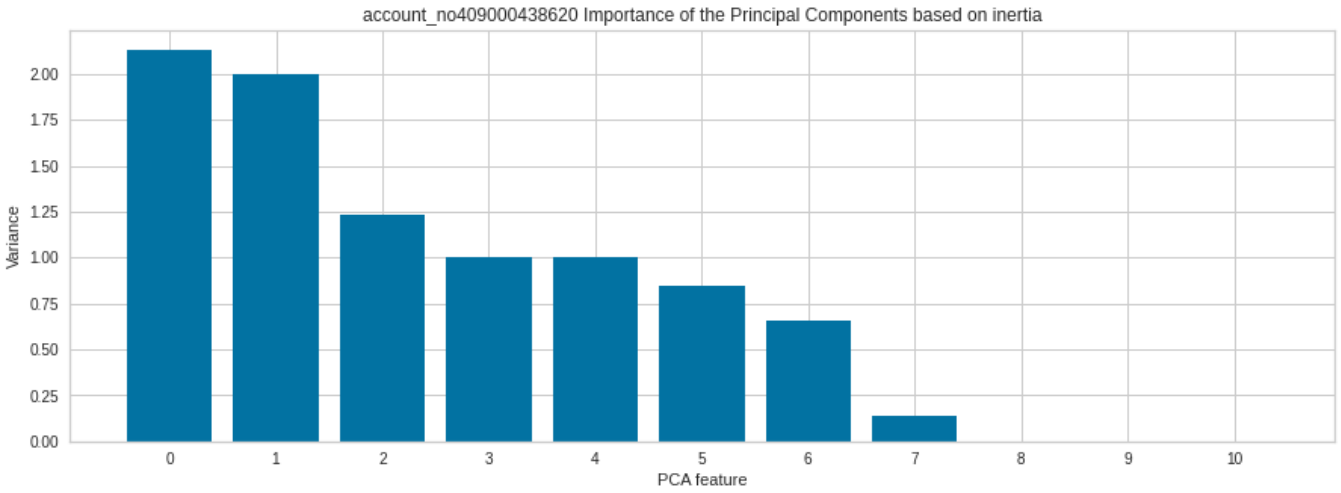

```
kmeans = KMeans(n_clusters=6)
kmeans.fit(acc3_kmeans_scaled)
labels = kmeans.labels_
```

```
fig = plt.figure(1, figsize=(6,6))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc3_kmeans_scaled.iloc[:,3], acc3_kmeans_scaled.iloc[:,4], acc3_km
ax.set_title(f'K MEANS {accounts[2]}', fontsize=14)
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
x = acc3_kmeans_scaled
pca = PCA()
pipeline = make_pipeline(pca)
pipeline.fit(x)
# Plot the principal components against their inertia
features = range(pca.n_components_)
_ = plt.figure(figsize=(15, 5))
_ = plt.bar(features, pca.explained_variance_)
_ = plt.xlabel('PCA feature')
_ = plt.ylabel('Variance')
_ = plt.xticks(features)
_ = plt.title(f"account_no{accounts[2]} Importance of the Principal Components
plt.show()
```




```
acc3_pca = pd.DataFrame(PCA(n_components=7).fit_transform(acc3_kmeans_scaled),
```

```
kmeans = KMeans(n_clusters=6)
kmeans.fit(acc3_pca)
labels = kmeans.predict(acc3_pca)

unique_elements, counts_elements = np.unique(labels, return_counts=True)
clusters = np.asarray((unique_elements, counts_elements))

outliers_fraction = 0.003
distance = getDistanceByPoint(acc3_pca, kmeans)
number_of_outliers = int(outliers_fraction*len(distance))
threshold = distance.nlargest(number_of_outliers).min()
acc3_pca['anomaly_kmeans'] = (distance >= threshold).astype(int)


acc3_pca.index = acc3.index
acc3_pca.anomaly_kmeans.value_counts()
```

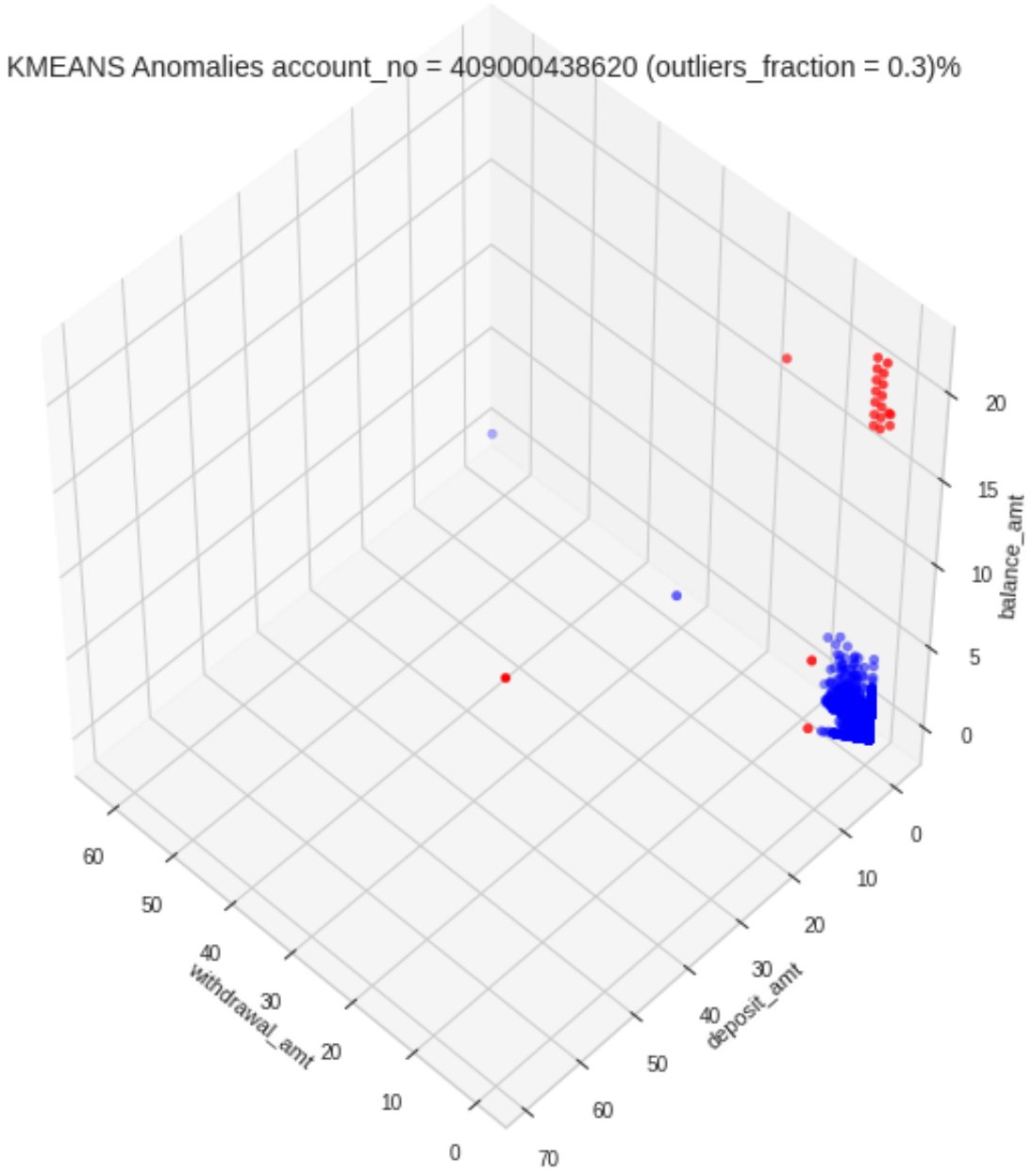
```
0    13414
1       40
Name: anomaly_kmeans, dtype: int64
```

```
acc3_kmeans_scaled['anomaly_kmeans'] = acc3_pca.anomaly_kmeans
bank_main['km_3'] = 0
bank_main.loc[acc3_kmeans_scaled.index,'km_3'] = acc3_kmeans_scaled['anomaly_k
bank_main['km_3'].value_counts()
```

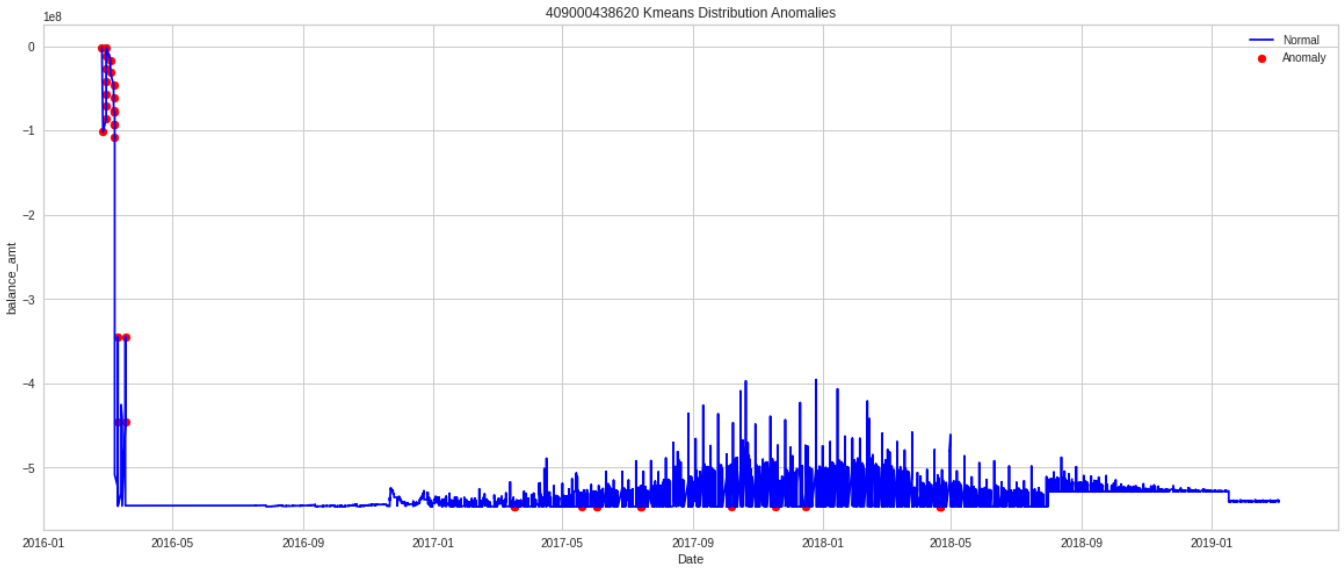
```
0    116161
1        40
Name: km_3, dtype: int64
```

```
labels = acc3_kmeans_scaled.anomaly_kmeans
colors = {0:'blue', 1:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc3_kmeans_scaled.iloc[:,3], acc3_kmeans_scaled.iloc[:,4], acc3_km
ax.set_title(f'KMEANS Anomalies account_no = {accounts[2]} (outliers_fraction =
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
acc3_kmeans['anomaly_kmeans'] = acc3_kmeans_scaled['anomaly_kmeans']
df = acc3_kmeans.copy()
a= df.loc[df['anomaly_kmeans']==1, ['date', 'balance_amt']]
plt.figure(figsize=(20,8))
plt.plot(df['date'], df['balance_amt'], color='blue', label='Normal')
plt.scatter(a['date'], a['balance_amt'], color='red', label='Anomaly')
plt.title(f'{accounts[2]} Kmeans Distribution Anomalies')
plt.xlabel('Date')
plt.ylabel('balance_amt')
plt.legend()
plt.show()
```




```
accounts[3]
```

```
'1196711'
```

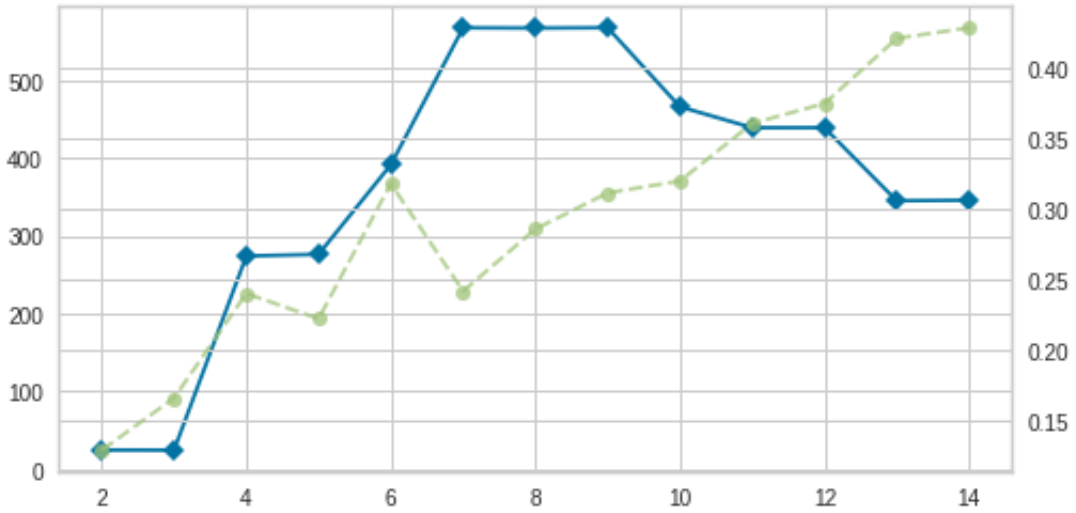
(IV) Customer account_no_1196711

```
acc4_kmeans = acc4.copy()
scaler = StandardScaler()
acc4_kmeans_scaled = pd.DataFrame(scaler.fit_transform(acc4_kmeans[acc4.columns
acc4_kmeans_scaled.set_index(acc4_kmeans.index, drop=True, inplace=True)
acc4_kmeans_scaled.head(3)
```

	day_diff	weekend_date	weekend_value_date	withdrawal_amt	deposit_ar
27046	-0.06111	-0.308943	-0.309496	-0.415321	-0.4182(
27047	-0.06111	-0.308943	-0.309496	-0.415321	-0.4184(
27048	-0.06111	-0.308943	-0.309496	-0.415321	-0.4183(

```
# Instantiate the clustering model and visualizer
visualizer = KElbowVisualizer(KMeans(), k=(2,15))
plt.figure(figsize=(8,4)).patch.set_facecolor('xkcd:white')
visualizer.fit(acc4_kmeans_scaled)       # Fit the data to the visualizer
# visualizer.show()        # Finalize and render the figure
```

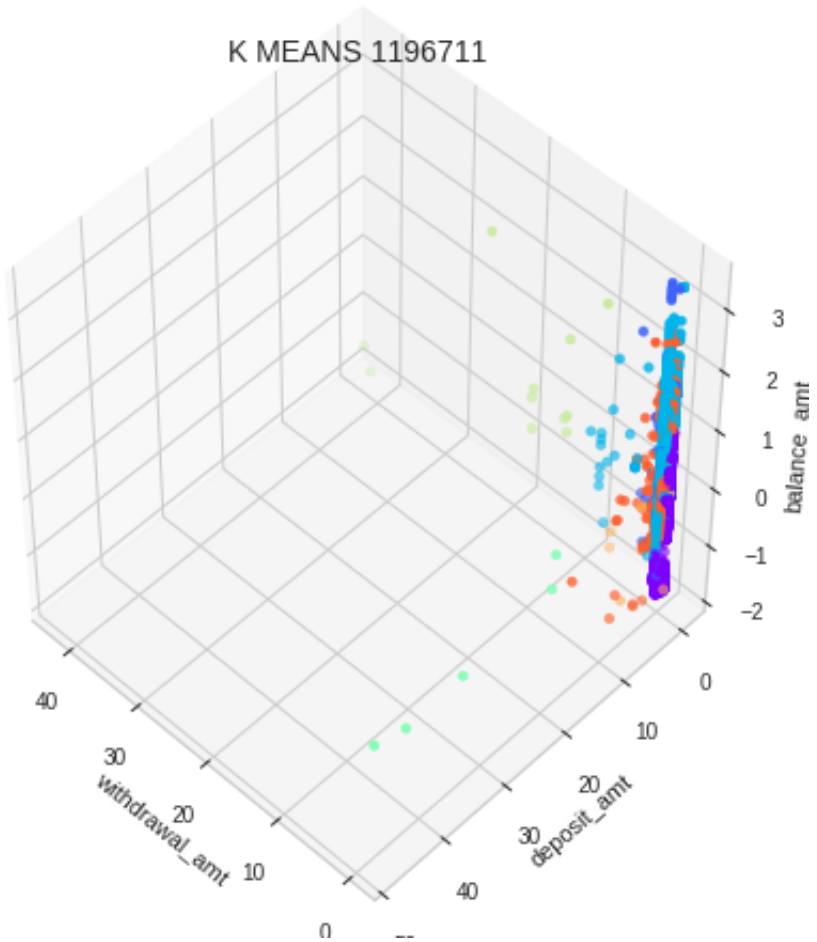
```
KElbowVisualizer(ax=<matplotlib.axes._subplots.AxesSubplot object at 0x7fa4
                 k=None, metric=None, model=None, timings=True)
```



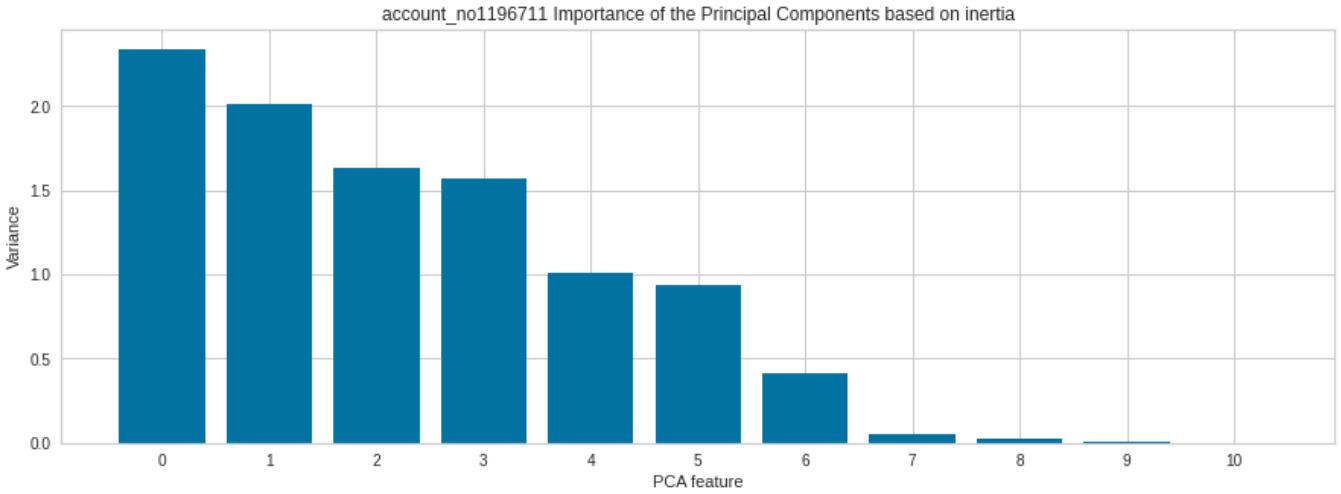

```
kmeans = KMeans(n_clusters=9)
kmeans.fit(acc4_kmeans_scaled)
labels = kmeans.labels_
```

```
fig = plt.figure(1, figsize=(6,6))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc4_kmeans_scaled.iloc[:,3], acc4_kmeans_scaled.iloc[:,4], acc4_km
ax.set_title(f'K MEANS {accounts[3]}', fontsize=14)
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
x = acc4_kmeans_scaled
pca = PCA()
pipeline = make_pipeline(pca)
pipeline.fit(x)
# Plot the principal components against their inertia
features = range(pca.n_components_)
_ = plt.figure(figsize=(15, 5))
_ = plt.bar(features, pca.explained_variance_)
_ = plt.xlabel('PCA feature')
_ = plt.ylabel('Variance')
_ = plt.xticks(features)
_ = plt.title(f"account_no{accounts[3]} Importance of the Principal Components
plt.show()
```




```
acc4_pca = pd.DataFrame(PCA(n_components=7).fit_transform(acc4_kmeans_scaled),
```

```
kmeans = KMeans(n_clusters=9)
kmeans.fit(acc4_pca)
labels = kmeans.predict(acc4_pca)

unique_elements, counts_elements = np.unique(labels, return_counts=True)
clusters = np.asarray((unique_elements, counts_elements))

outliers_fraction = 0.005
distance = getDistanceByPoint(acc4_pca, kmeans)

number_of_outliers = int(outliers_fraction*len(distance))
threshold = distance.nlargest(number_of_outliers).min()
acc4_pca['anomaly_kmeans'] = (distance >= threshold).astype(int)


acc4_pca.index = acc4.index
acc4_pca.anomaly_kmeans.value_counts()
```

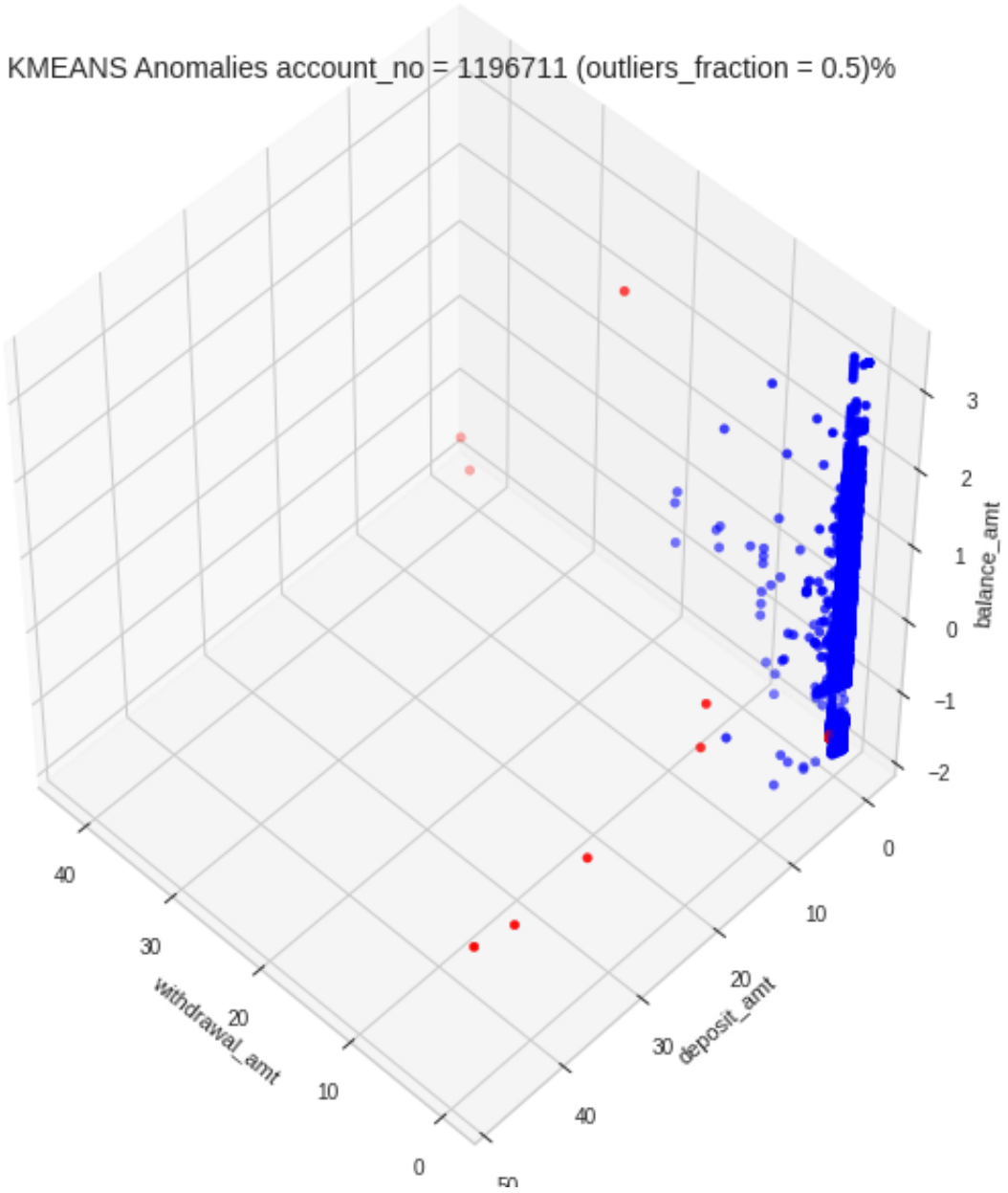
```
0    10484
1       52
Name: anomaly_kmeans, dtype: int64
```

```
acc4_kmeans_scaled['anomaly_kmeans'] = acc4_pca.anomaly_kmeans
bank_main['km_4'] = 0
bank_main.loc[acc4_kmeans_scaled.index,'km_4'] = acc4_kmeans_scaled['anomaly_k
bank_main['km_4'].value_counts()
```

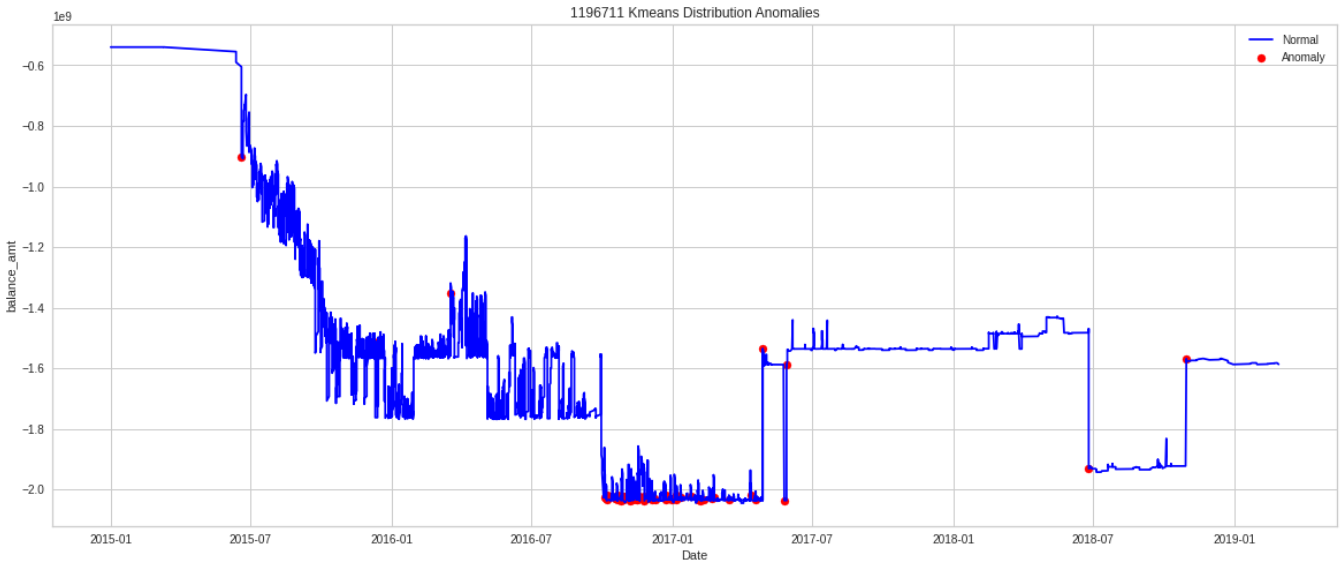
```
0    116149
1        52
Name: km_4, dtype: int64
```

```
labels = acc4_kmeans_scaled.anomaly_kmeans
colors = {0:'blue', 1:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc4_kmeans_scaled.iloc[:,3], acc4_kmeans_scaled.iloc[:,4], acc4_km
ax.set_title(f'KMEANS Anomalies account_no = {accounts[3]} (outliers_fraction =
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
acc4_kmeans['anomaly_kmeans'] = acc4_kmeans_scaled['anomaly_kmeans']
df = acc4_kmeans.copy()
a= df.loc[df['anomaly_kmeans']==1, ['date', 'balance_amt']]
plt.figure(figsize=(20,8))
plt.plot(df['date'], df['balance_amt'], color='blue', label='Normal')
plt.scatter(a['date'], a['balance_amt'], color='red', label='Anomaly')
plt.title(f'{accounts[3]} Kmeans Distribution Anomalies')
plt.xlabel('Date')
plt.ylabel('balance_amt')
plt.legend()
plt.show()
```




```
accounts[4]
```

```
'409000493210'
```

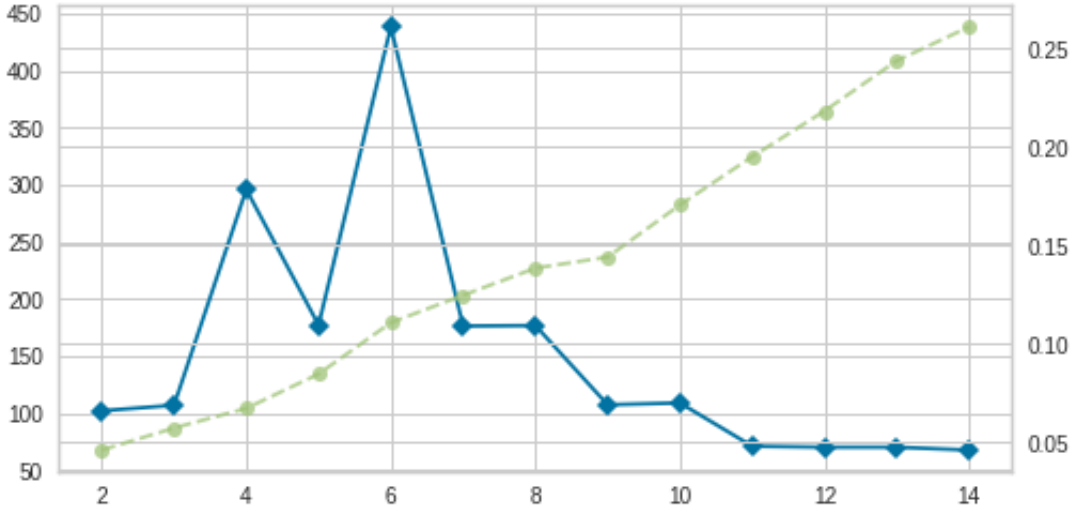
(V) Customer account_no_409000493210

```
acc5_kmeans = acc5.copy()
scaler = StandardScaler()
acc5_kmeans_scaled = pd.DataFrame(scaler.fit_transform(acc5_kmeans[acc5.columns
acc5_kmeans_scaled.set_index(acc5_kmeans.index, drop=True, inplace=True)
acc5_kmeans_scaled.head(3)
```

	day_diff	weekend_date	weekend_value_date	withdrawal_amt	deposit_am
7578	0.0	-0.249713	-0.249713	-0.042609	1.20359
7579	0.0	-0.249713	-0.249713	-0.042227	-0.04235
7580	0.0	-0.249713	-0.249713	-0.042555	-0.04235

```
# Instantiate the clustering model and visualizer
visualizer = KElbowVisualizer(KMeans(), k=(2,15))
plt.figure(figsize=(8,4)).patch.set_facecolor('xkcd:white')
visualizer.fit(acc5_kmeans_scaled)       # Fit the data to the visualizer
# visualizer.show()        # Finalize and render the figure
```

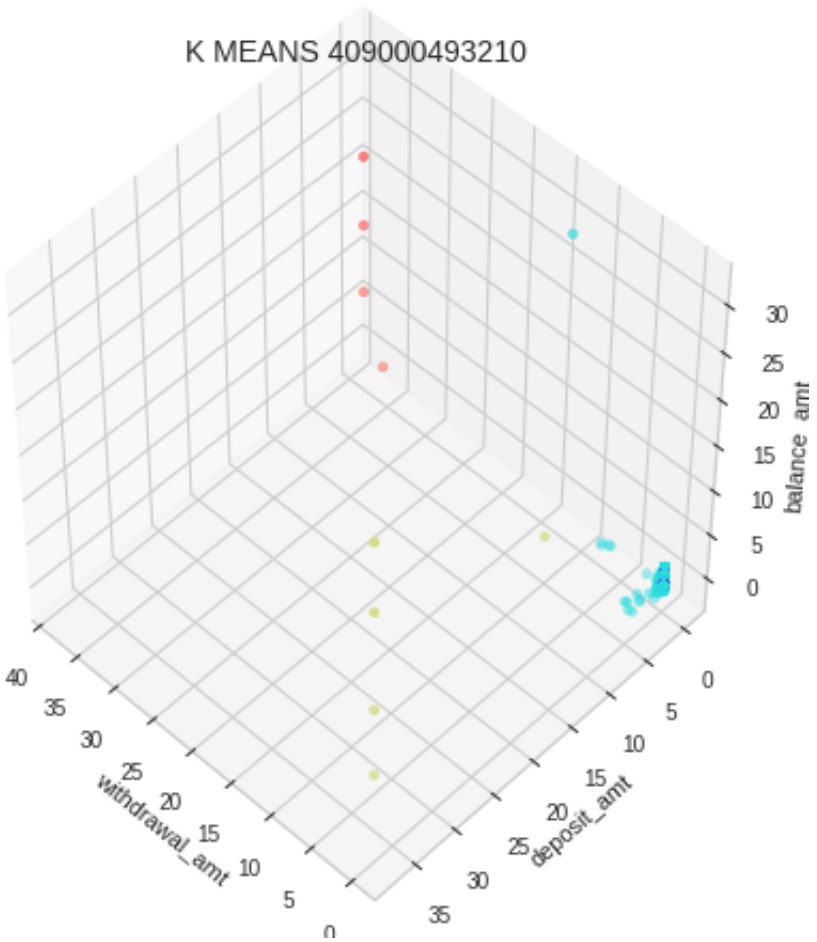
```
KElbowVisualizer(ax=<matplotlib.axes._subplots.AxesSubplot object at 0x7fa4
                 k=None, metric=None, model=None, timings=True)
```



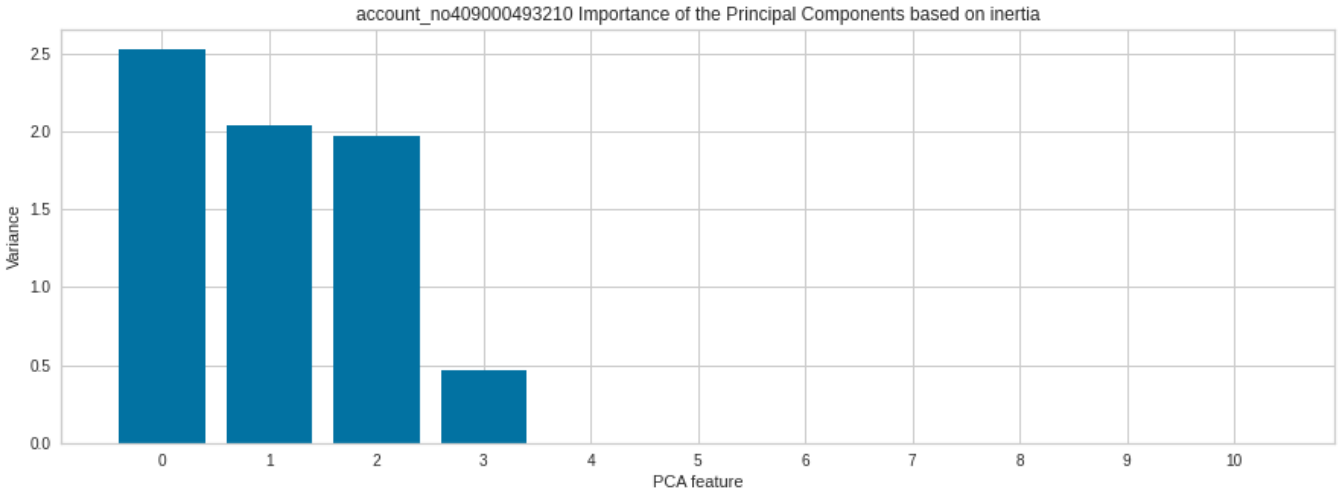

```
kmeans = KMeans(n_clusters=4)
kmeans.fit(acc5_kmeans_scaled)
labels = kmeans.labels_
```

```
fig = plt.figure(1, figsize=(6,6))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc5_kmeans_scaled.iloc[:,3], acc5_kmeans_scaled.iloc[:,4], acc5_km
ax.set_title(f'K MEANS {accounts[4]}', fontsize=14)
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
x = acc5_kmeans_scaled
pca = PCA()
pipeline = make_pipeline(pca)
pipeline.fit(x)
# Plot the principal components against their inertia
features = range(pca.n_components_)
_ = plt.figure(figsize=(15, 5))
_ = plt.bar(features, pca.explained_variance_)
_ = plt.xlabel('PCA feature')
_ = plt.ylabel('Variance')
_ = plt.xticks(features)
_ = plt.title(f"account_no{accounts[4]} Importance of the Principal Components
plt.show()
```




```
acc5_pca = pd.DataFrame(PCA(n_components=3).fit_transform(acc5_kmeans_scaled),
```

```
kmeans = KMeans(n_clusters=4)
kmeans.fit(acc5_pca)
labels = kmeans.predict(acc5_pca)

unique_elements, counts_elements = np.unique(labels, return_counts=True)
clusters = np.asarray((unique_elements, counts_elements))

outliers_fraction = 0.005
distance = getDistanceByPoint(acc5_pca, kmeans)

number_of_outliers = int(outliers_fraction*len(distance))
threshold = distance.nlargest(number_of_outliers).min()
acc5_pca['anomaly_kmeans'] = (distance >= threshold).astype(int)


acc5_pca.index = acc5.index
acc5_pca.anomaly_kmeans.value_counts()
```

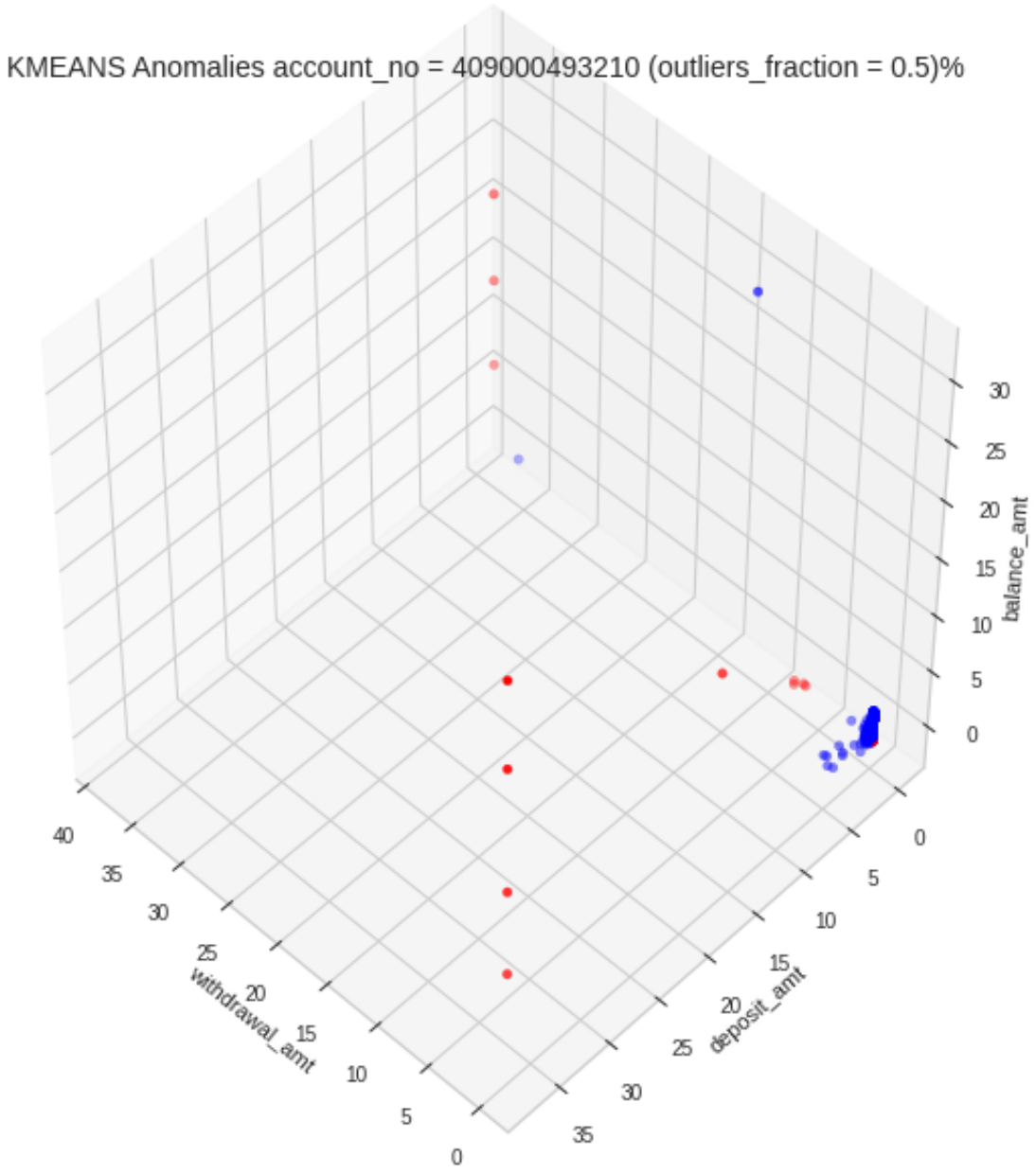
```
0    5984
1      30
Name: anomaly_kmeans, dtype: int64
```

```
acc5_kmeans_scaled['anomaly_kmeans'] = acc5_pca.anomaly_kmeans
bank_main['km_5'] = 0
bank_main.loc[acc5_kmeans_scaled.index,'km_5'] = acc5_kmeans_scaled['anomaly_k
bank_main['km_5'].value_counts()
```

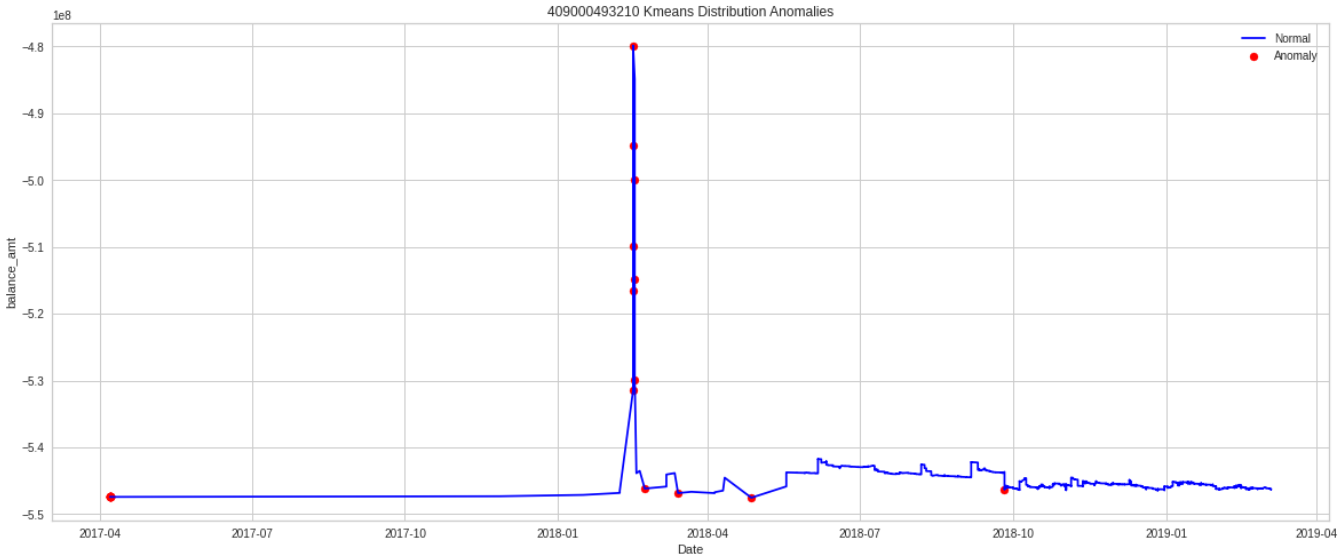
```
0    116171
1        30
Name: km_5, dtype: int64
```

```
labels = acc5_kmeans_scaled.anomaly_kmeans
colors = {0:'blue', 1:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc5_kmeans_scaled.iloc[:,3], acc5_kmeans_scaled.iloc[:,4], acc5_km
ax.set_title(f'KMEANS Anomalies account_no = {accounts[4]} (outliers_fraction =
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
acc5_kmeans['anomaly_kmeans'] = acc5_kmeans_scaled['anomaly_kmeans']
df = acc5_kmeans.copy()
a= df.loc[df['anomaly_kmeans']==1, ['date', 'balance_amt']]
plt.figure(figsize=(20,8))
plt.plot(df['date'], df['balance_amt'], color='blue', label='Normal')
plt.scatter(a['date'], a['balance_amt'], color='red', label='Anomaly')
plt.title(f'{accounts[4]} Kmeans Distribution Anomalies')
plt.xlabel('Date')
plt.ylabel('balance_amt')
plt.legend()
plt.show()
```



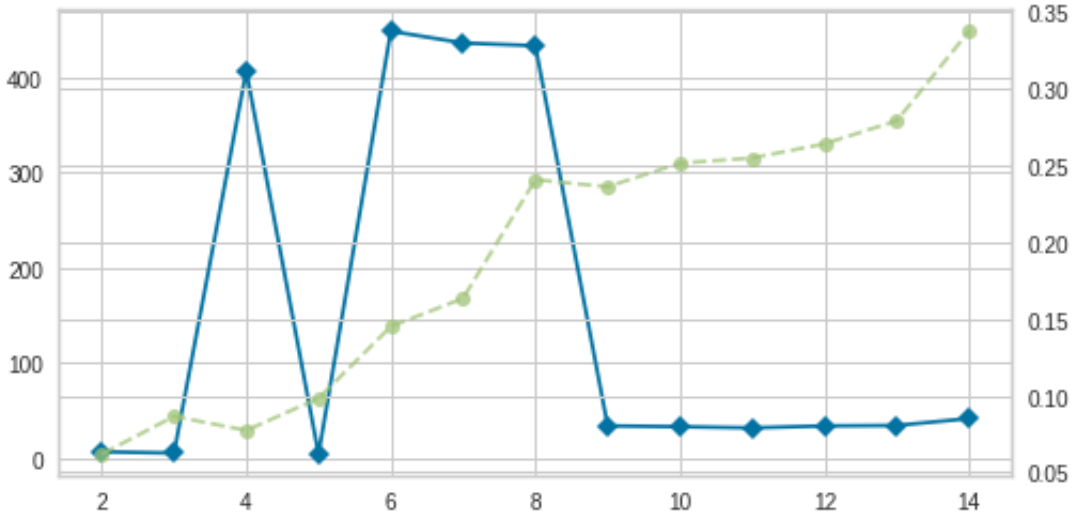
(V) Customer account_no_409000438611

```
acc6_kmeans = acc6.copy()
scaler = StandardScaler()
acc6_kmeans_scaled = pd.DataFrame(scaler.fit_transform(acc6_kmeans[acc6.columns
acc6_kmeans_scaled.set_index(acc6_kmeans.index, drop=True, inplace=True)
acc6_kmeans_scaled.head(3)
```

	day_diff	weekend_date	weekend_value_date	withdrawal_amt	deposit_am
2990	0.0	-0.280204	-0.280204	-0.217132	52.87383
2991	0.0	-0.280204	-0.280204	27.304861	-0.32047
2992	0.0	-0.280204	-0.280204	8.251173	-0.32047

```
# Instantiate the clustering model and visualizer
visualizer = KElbowVisualizer(KMeans(), k=(2,15))
plt.figure(figsize=(8,4)).patch.set_facecolor('xkcd:white')
visualizer.fit(acc6_kmeans_scaled)       # Fit the data to the visualizer
# visualizer.show()        # Finalize and render the figure
```

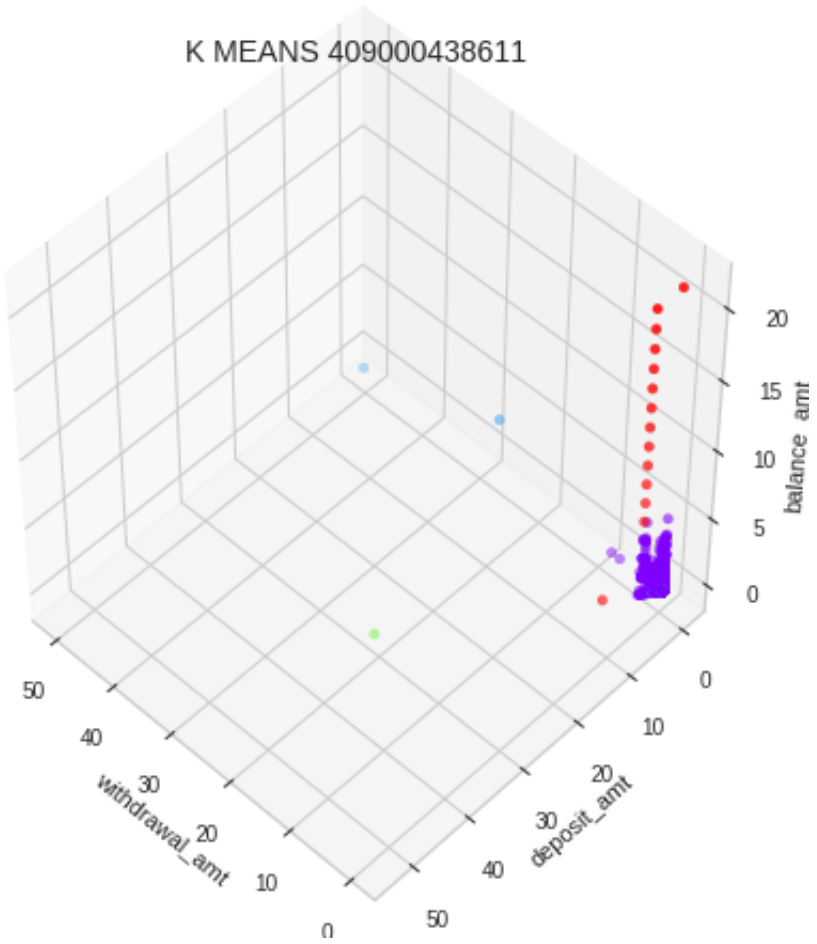
```
KElbowVisualizer(ax=<matplotlib.axes._subplots.AxesSubplot object at 0x7fa4
                 k=None, metric=None, model=None, timings=True)
```



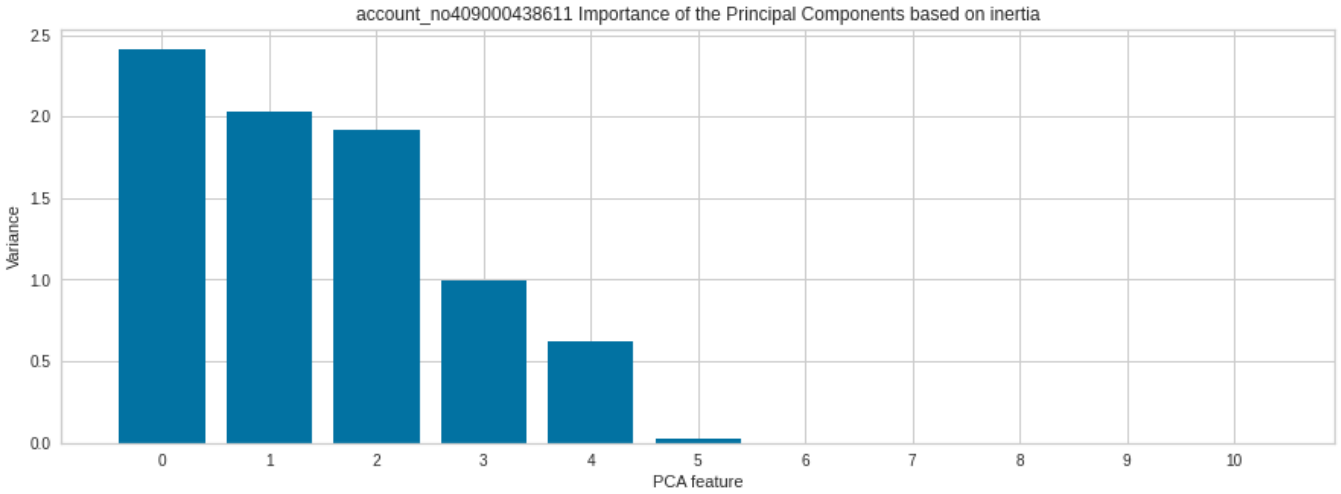

```
kmeans = KMeans(n_clusters=6)
kmeans.fit(acc6_kmeans_scaled)
labels = kmeans.labels_
```

```
fig = plt.figure(1, figsize=(6,6))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc6_kmeans_scaled.iloc[:,3], acc6_kmeans_scaled.iloc[:,4], acc6_km
ax.set_title(f'K MEANS {accounts[5]}', fontsize=14)
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
x = acc6_kmeans_scaled
pca = PCA()
pipeline = make_pipeline(pca)
pipeline.fit(x)
# Plot the principal components against their inertia
features = range(pca.n_components_)
_ = plt.figure(figsize=(15, 5))
_ = plt.bar(features, pca.explained_variance_)
_ = plt.xlabel('PCA feature')
_ = plt.ylabel('Variance')
_ = plt.xticks(features)
_ = plt.title(f"account_no{accounts[5]} Importance of the Principal Components
plt.show()
```




```
acc6_pca = pd.DataFrame(PCA(n_components=5).fit_transform(acc6_kmeans_scaled),
```

```
kmeans = KMeans(n_clusters=6)
kmeans.fit(acc6_pca)
labels = kmeans.predict(acc6_pca)

unique_elements, counts_elements = np.unique(labels, return_counts=True)
clusters = np.asarray((unique_elements, counts_elements))

outliers_fraction = 0.005
distance = getDistanceByPoint(acc6_pca, kmeans)

number_of_outliers = int(outliers_fraction*len(distance))
threshold = distance.nlargest(number_of_outliers).min()
acc6_pca['anomaly_kmeans'] = (distance >= threshold).astype(int)


acc6_pca.index = acc6.index
acc6_pca.anomaly_kmeans.value_counts()
```

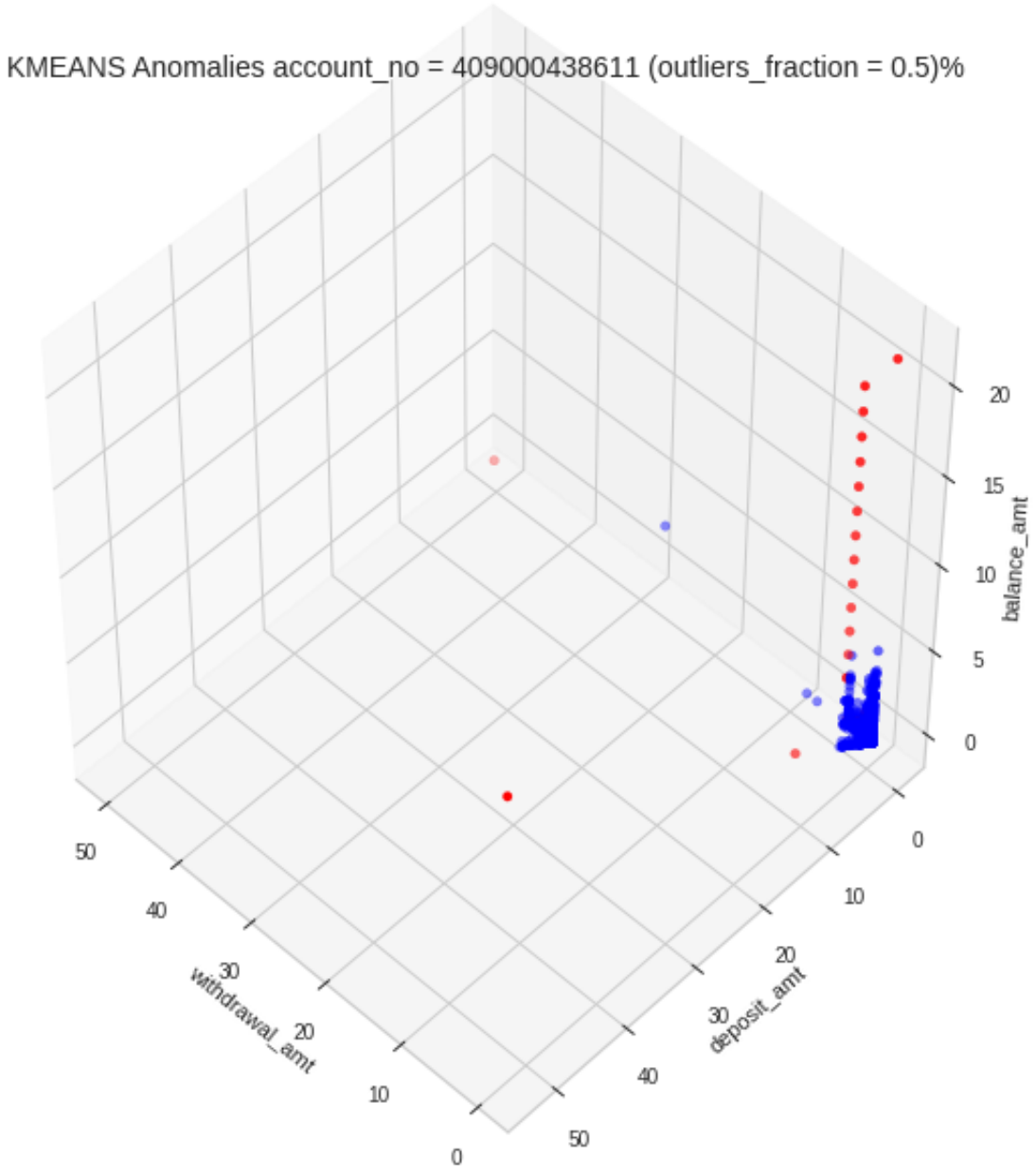
```
0    4566
1      22
Name: anomaly_kmeans, dtype: int64
```

```
acc6_kmeans_scaled['anomaly_kmeans'] = acc6_pca.anomaly_kmeans
bank_main['km_6'] = 0
bank_main.loc[acc6_kmeans_scaled.index,'km_6'] = acc6_kmeans_scaled['anomaly_k
bank_main['km_6'].value_counts()
```

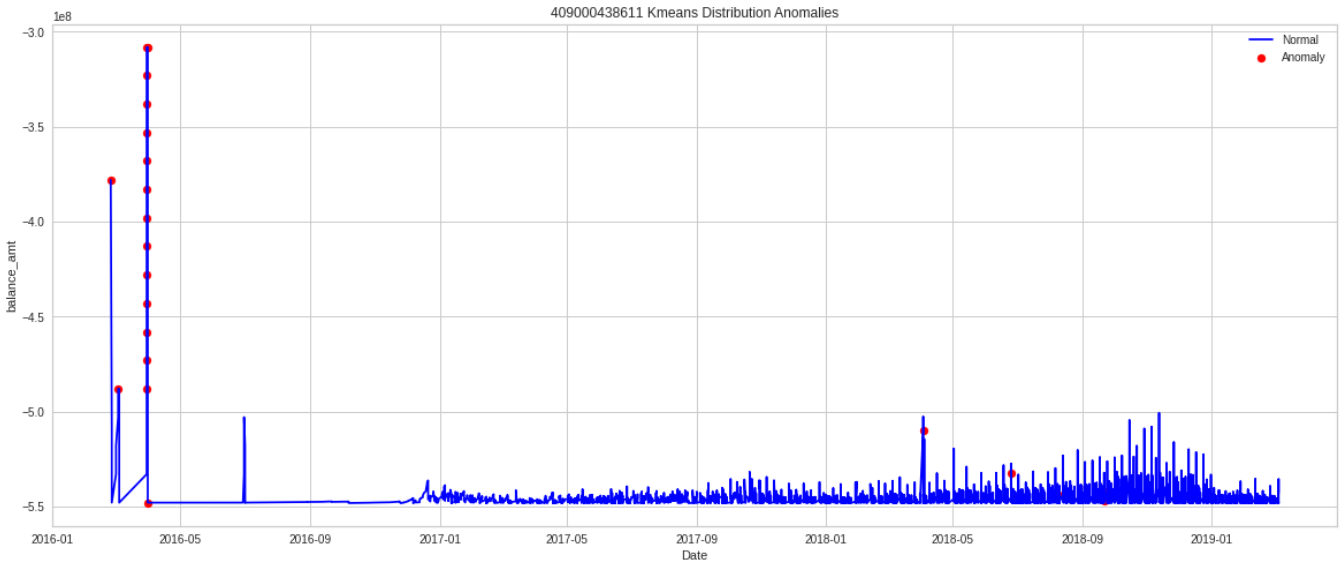
```
0    116179
1        22
Name: km_6, dtype: int64
```

```
labels = acc6_kmeans_scaled.anomaly_kmeans
colors = {0:'blue', 1:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc6_kmeans_scaled.iloc[:,3], acc6_kmeans_scaled.iloc[:,4], acc6_km
ax.set_title(f'KMEANS Anomalies account_no = {accounts[5]} (outliers_fraction =
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
acc6_kmeans['anomaly_kmeans'] = acc6_kmeans_scaled['anomaly_kmeans']
df = acc6_kmeans.copy()
a= df.loc[df['anomaly_kmeans']==1, ['date', 'balance_amt']]
plt.figure(figsize=(20,8))
plt.plot(df['date'], df['balance_amt'], color='blue', label='Normal')
plt.scatter(a['date'], a['balance_amt'], color='red', label='Anomaly')
plt.title(f'{accounts[5]} Kmeans Distribution Anomalies')
plt.xlabel('Date')
plt.ylabel('balance_amt')
plt.legend()
plt.show()
```



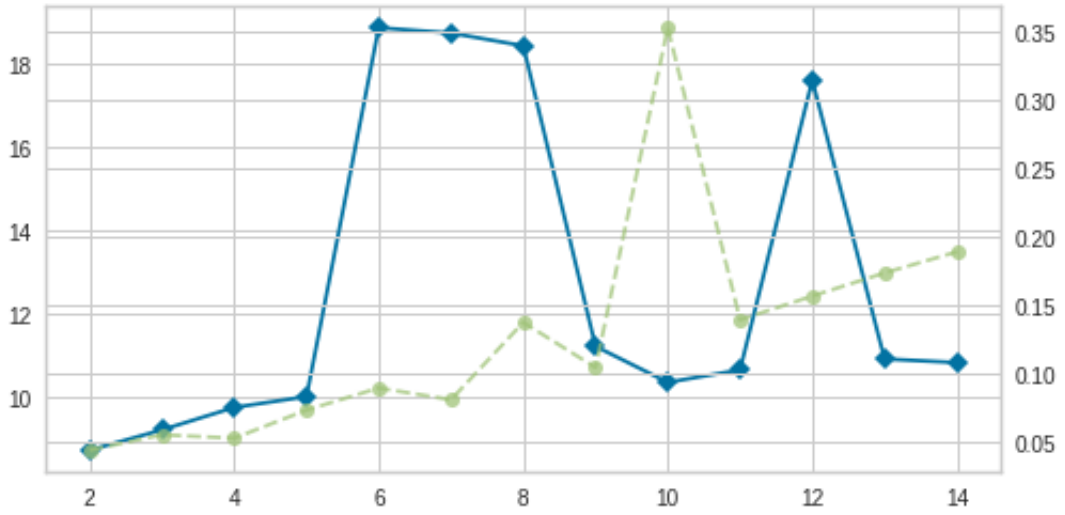
(VII) Customer account_no_409000611074

```
acc7_kmeans = acc7.copy()
scaler = StandardScaler()
acc7_kmeans_scaled = pd.DataFrame(scaler.fit_transform(acc7_kmeans[acc7.columns
acc7_kmeans_scaled.set_index(acc7_kmeans.index, drop=True, inplace=True)
acc7_kmeans_scaled.head(3)
```

	day_diff	weekend_date	weekend_value_date	withdrawal_amt	deposit_amt	l
0	0.0	-0.269481	-0.269481	-0.687913	3.664767	
1	0.0	-0.269481	-0.269481	-0.687913	3.664767	
2	0.0	-0.269481	-0.269481	-0.687913	1.550196	

```
# Instantiate the clustering model and visualizer
visualizer = KElbowVisualizer(KMeans(), k=(2,15))
plt.figure(figsize=(8,4)).patch.set_facecolor('xkcd:white')
visualizer.fit(acc7_kmeans_scaled)       # Fit the data to the visualizer
# visualizer.show()        # Finalize and render the figure
```

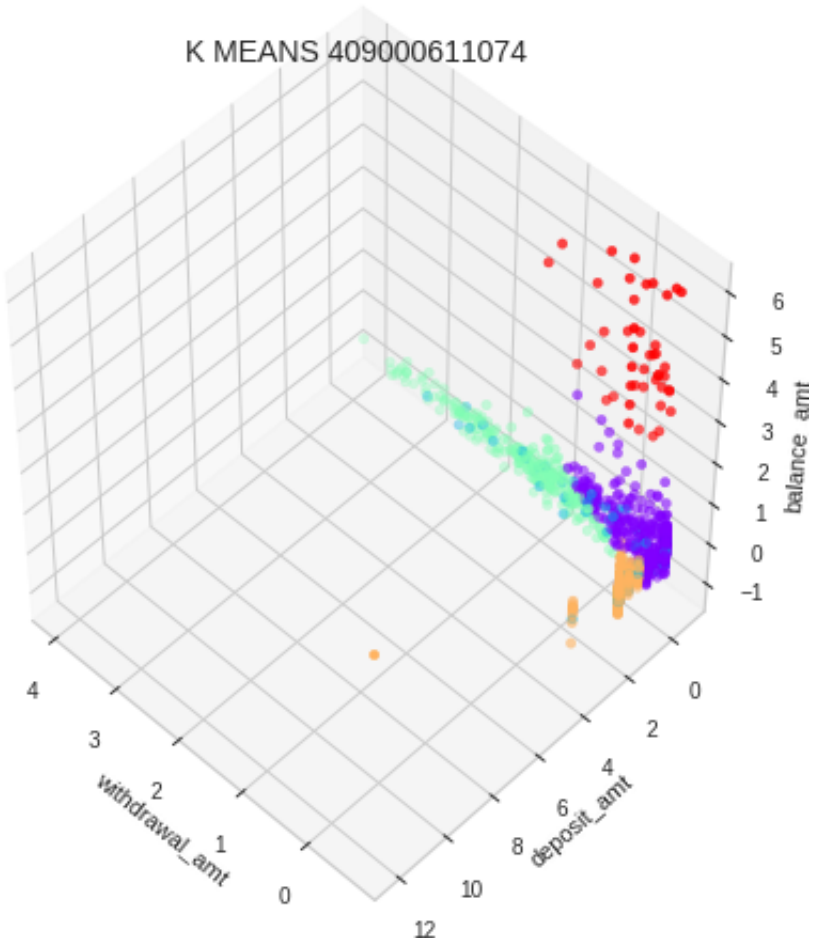
```
KElbowVisualizer(ax=<matplotlib.axes._subplots.AxesSubplot object at 0x7fa4
                 k=None, metric=None, model=None, timings=True)
```



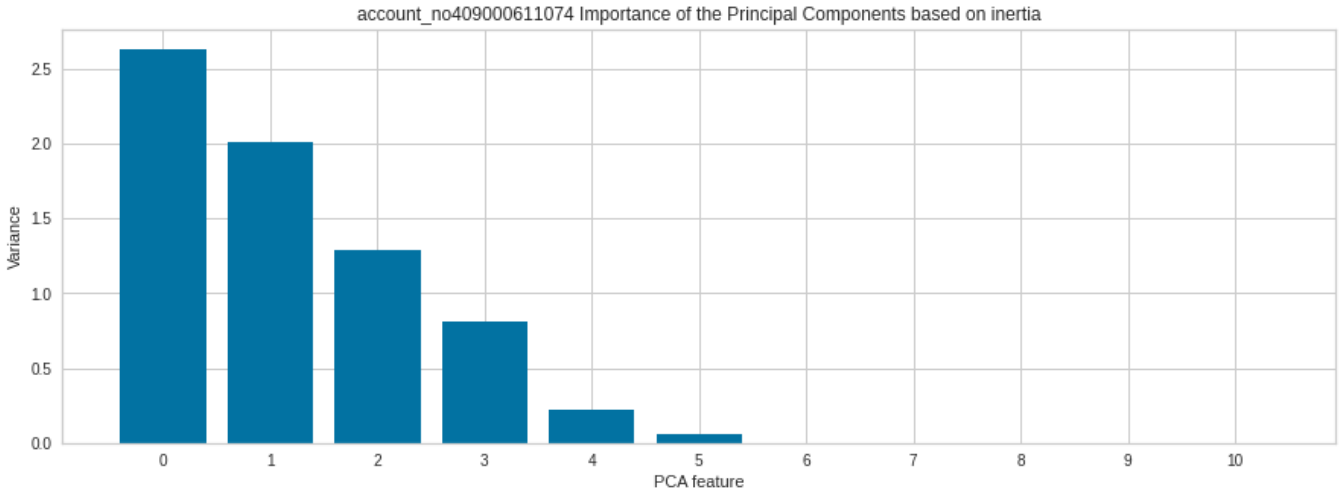

```
kmeans = KMeans(n_clusters=5)
kmeans.fit(acc7_kmeans_scaled)
labels = kmeans.labels_
```

```
fig = plt.figure(1, figsize=(6,6))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc7_kmeans_scaled.iloc[:,3], acc7_kmeans_scaled.iloc[:,4], acc7_km
ax.set_title(f'K MEANS {accounts[6]}', fontsize=14)
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
x = acc7_kmeans_scaled
pca = PCA()
pipeline = make_pipeline(pca)
pipeline.fit(x)
# Plot the principal components against their inertia
features = range(pca.n_components_)
_ = plt.figure(figsize=(15, 5))
_ = plt.bar(features, pca.explained_variance_)
_ = plt.xlabel('PCA feature')
_ = plt.ylabel('Variance')
_ = plt.xticks(features)
_ = plt.title(f"account_no{accounts[6]} Importance of the Principal Components
plt.show()
```




```
acc7_pca = pd.DataFrame(PCA(n_components=5).fit_transform(acc7_kmeans_scaled),
```

```
kmeans = KMeans(n_clusters=5)
kmeans.fit(acc7_pca)
labels = kmeans.predict(acc7_pca)

unique_elements, counts_elements = np.unique(labels, return_counts=True)
clusters = np.asarray((unique_elements, counts_elements))

outliers_fraction = 0.01
distance = getDistanceByPoint(acc7_pca, kmeans)

number_of_outliers = int(outliers_fraction*len(distance))
threshold = distance.nlargest(number_of_outliers).min()
acc7_pca['anomaly_kmeans'] = (distance >= threshold).astype(int)


acc7_pca.index = acc7.index
acc7_pca.anomaly_kmeans.value_counts()
```

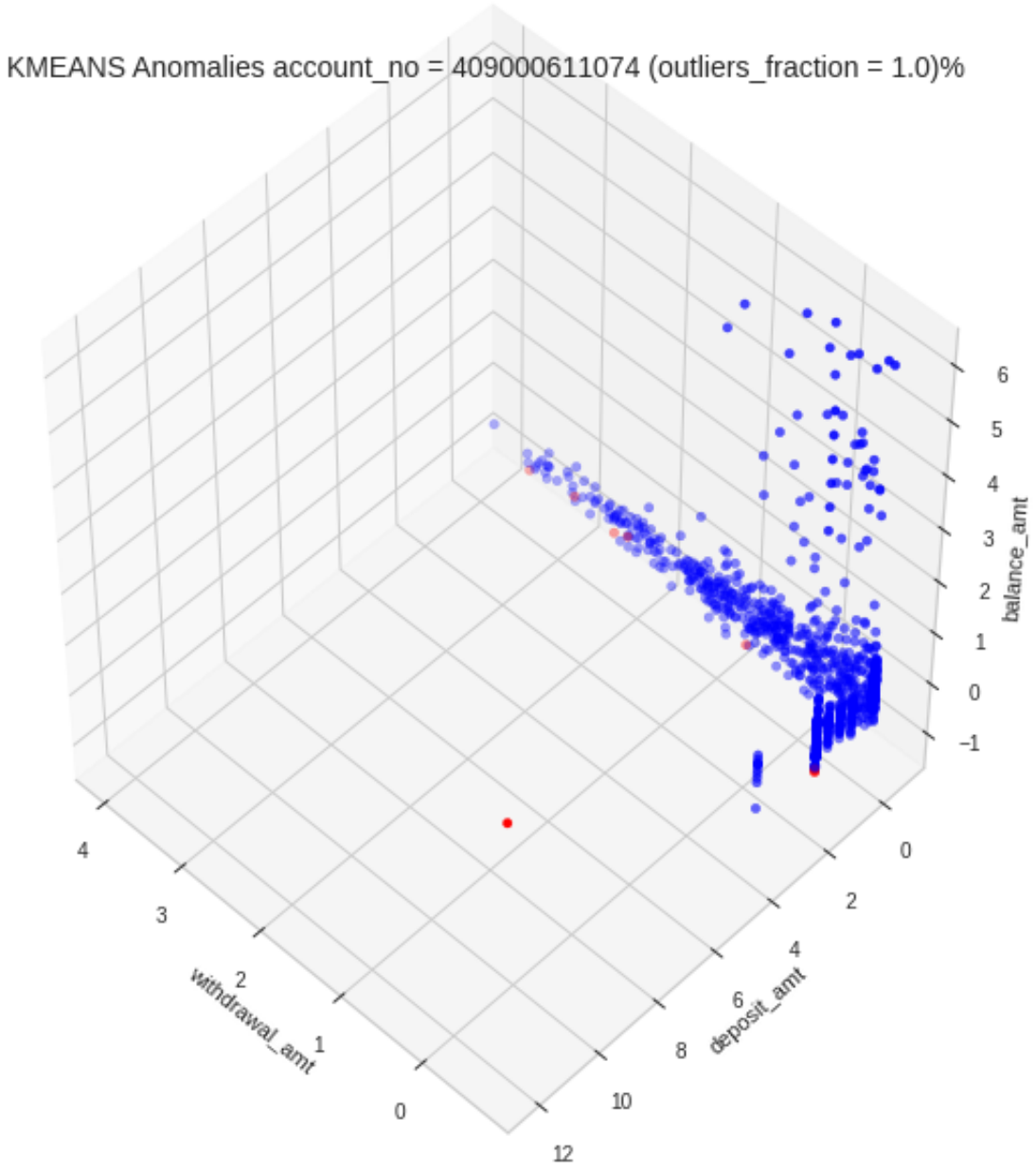
```
0    1083
1      10
Name: anomaly_kmeans, dtype: int64
```

```
acc7_kmeans_scaled['anomaly_kmeans'] = acc7_pca.anomaly_kmeans
bank_main['km_7'] = 0
bank_main.loc[acc7_kmeans_scaled.index,'km_7'] = acc7_kmeans_scaled['anomaly_k
bank_main['km_7'].value_counts()
```

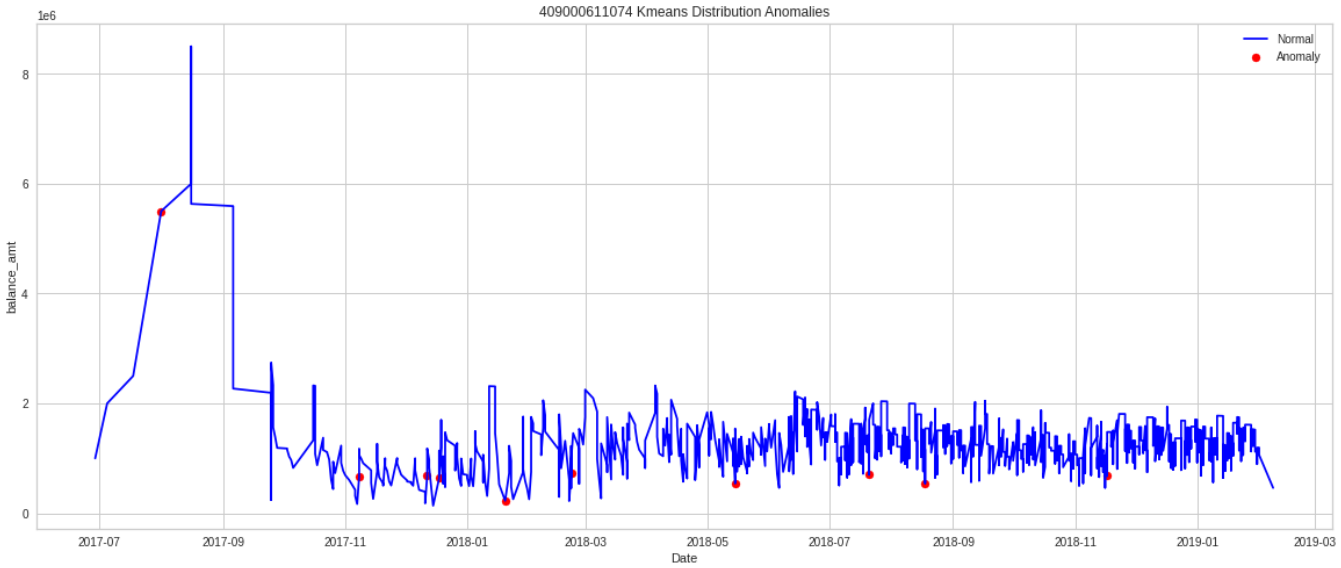
```
0    116191
1        10
Name: km_7, dtype: int64
```

```
labels = acc7_kmeans_scaled.anomaly_kmeans
colors = {0:'blue', 1:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc7_kmeans_scaled.iloc[:,3], acc7_kmeans_scaled.iloc[:,4], acc7_km
ax.set_title(f'KMEANS Anomalies account_no = {accounts[6]} (outliers_fraction =
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
acc7_kmeans['anomaly_kmeans'] = acc7_kmeans_scaled['anomaly_kmeans']
df = acc7_kmeans.copy()
a= df.loc[df['anomaly_kmeans']==1, ['date', 'balance_amt']]
plt.figure(figsize=(20,8))
plt.plot(df['date'], df['balance_amt'], color='blue', label='Normal')
plt.scatter(a['date'], a['balance_amt'], color='red', label='Anomaly')
plt.title(f'{accounts[6]} Kmeans Distribution Anomalies')
plt.xlabel('Date')
plt.ylabel('balance_amt')
plt.legend()
plt.show()
```



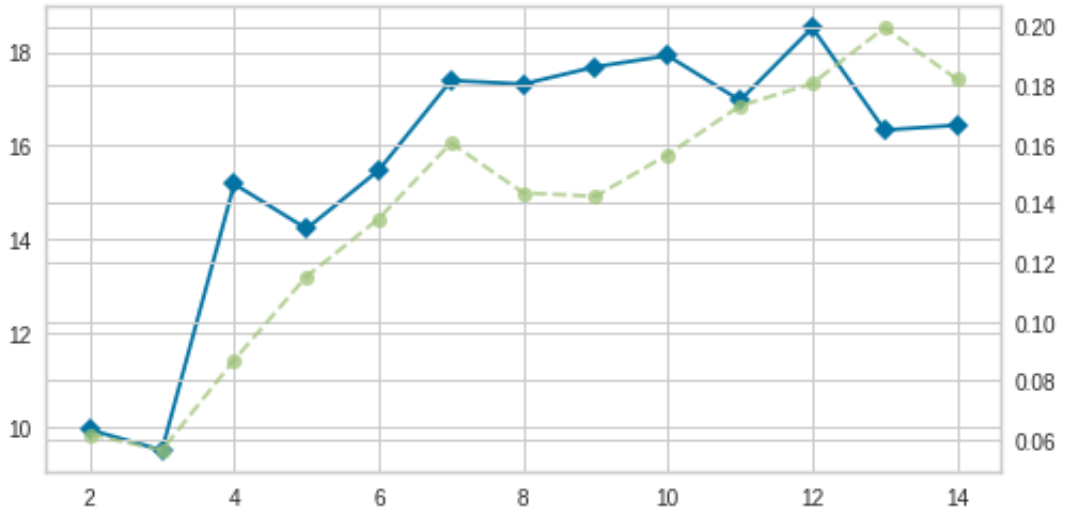
(VIII) Customer account_no_409000493201

```
acc8_kmeans = acc8.copy()
scaler = StandardScaler()
acc8_kmeans_scaled = pd.DataFrame(scaler.fit_transform(acc8_kmeans[acc8.columns
acc8_kmeans_scaled.set_index(acc8_kmeans.index, drop=True, inplace=True)
acc8_kmeans_scaled.head(3)
```

	day_diff	weekend_date	weekend_value_date	withdrawal_amt	deposit_am
1093	0.0	-0.261873	-0.261873	-0.450731	3.00717
1094	0.0	-0.261873	-0.261873	-0.446770	-0.67472
1095	0.0	-0.261873	-0.261873	-0.449547	-0.67472

```
# Instantiate the clustering model and visualizer
visualizer = KElbowVisualizer(KMeans(), k=(2,15))
plt.figure(figsize=(8,4)).patch.set_facecolor('xkcd:white')
visualizer.fit(acc8_kmeans_scaled)       # Fit the data to the visualizer
# visualizer.show()        # Finalize and render the figure
```

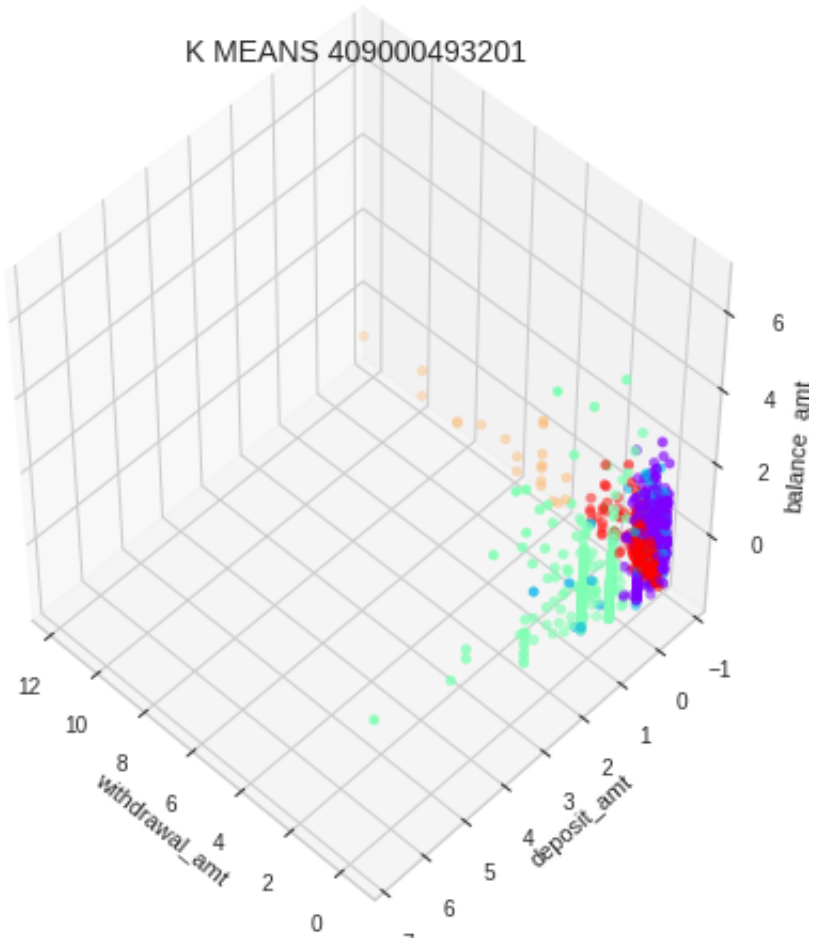
```
KElbowVisualizer(ax=<matplotlib.axes._subplots.AxesSubplot object at 0x7fa4
                 k=None, metric=None, model=None, timings=True)
```



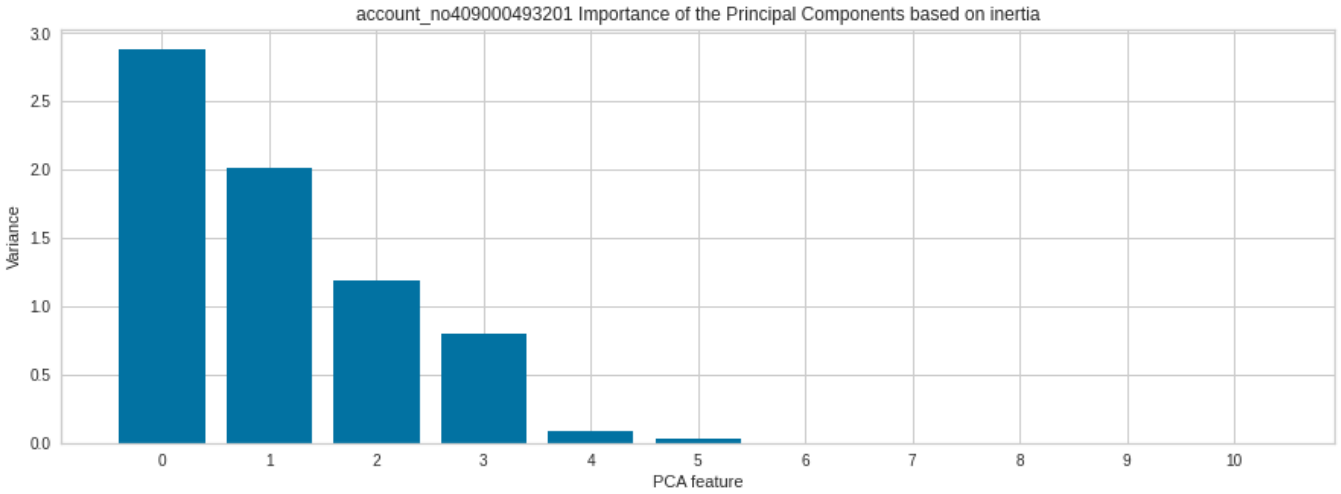

```
kmeans = KMeans(n_clusters=5)
kmeans.fit(acc8_kmeans_scaled)
labels = kmeans.labels_
```

```
fig = plt.figure(1, figsize=(6,6))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc8_kmeans_scaled.iloc[:,3], acc8_kmeans_scaled.iloc[:,4], acc8_km
ax.set_title(f'K MEANS {accounts[7]}', fontsize=14)
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
x = acc8_kmeans_scaled
pca = PCA()
pipeline = make_pipeline(pca)
pipeline.fit(x)
# Plot the principal components against their inertia
features = range(pca.n_components_)
_ = plt.figure(figsize=(15, 5))
_ = plt.bar(features, pca.explained_variance_)
_ = plt.xlabel('PCA feature')
_ = plt.ylabel('Variance')
_ = plt.xticks(features)
_ = plt.title(f"account_no{accounts[7]} Importance of the Principal Components
plt.show()
```




```
acc8_pca = pd.DataFrame(PCA(n_components=5).fit_transform(acc8_kmeans_scaled),
```

```
kmeans = KMeans(n_clusters=5)
kmeans.fit(acc8_pca)
labels = kmeans.predict(acc8_pca)

unique_elements, counts_elements = np.unique(labels, return_counts=True)
clusters = np.asarray((unique_elements, counts_elements))

outliers_fraction = 0.007
distance = getDistanceByPoint(acc8_pca, kmeans)

number_of_outliers = int(outliers_fraction*len(distance))
threshold = distance.nlargest(number_of_outliers).min()
acc8_pca['anomaly_kmeans'] = (distance >= threshold).astype(int)


acc8_pca.index = acc8.index
acc8_pca.anomaly_kmeans.value_counts()
```

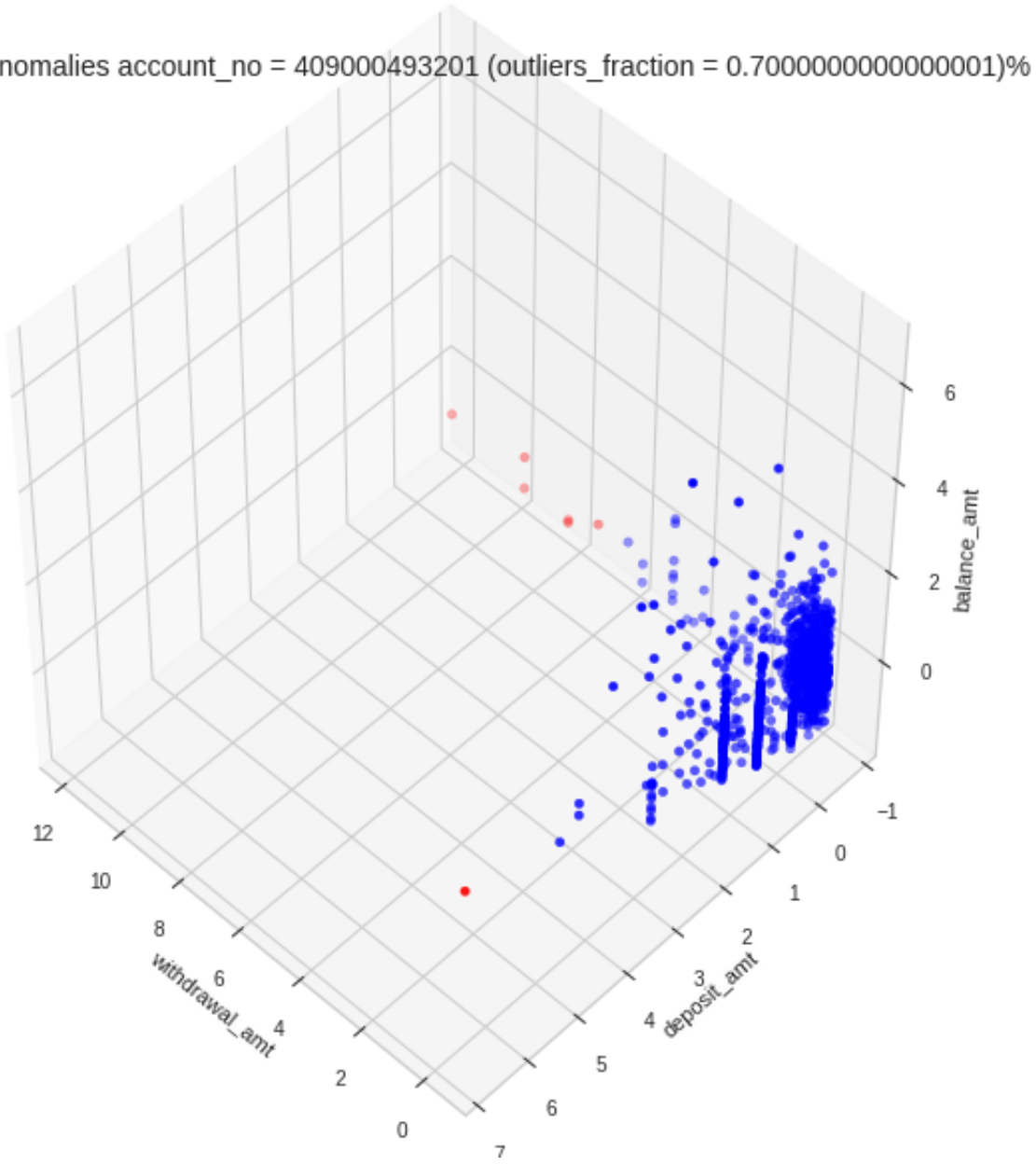
```
0    1037
1       7
Name: anomaly_kmeans, dtype: int64
```

```
acc8_kmeans_scaled['anomaly_kmeans'] = acc8_pca.anomaly_kmeans
bank_main['km_8'] = 0
bank_main.loc[acc8_kmeans_scaled.index,'km_8'] = acc8_kmeans_scaled['anomaly_k
bank_main['km_8'].value_counts()
```

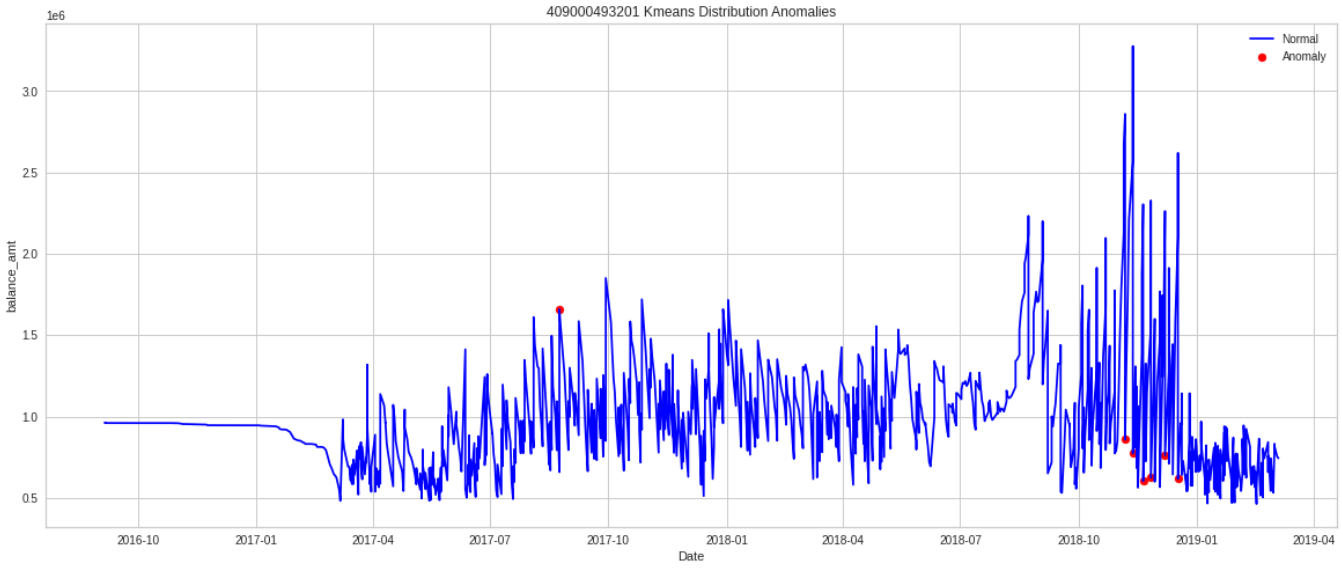
```
0    116194
1         7
Name: km_8, dtype: int64
```

```
labels = acc8_kmeans_scaled.anomaly_kmeans
colors = {0:'blue', 1:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc8_kmeans_scaled.iloc[:,3], acc8_kmeans_scaled.iloc[:,4], acc8_km
ax.set_title(f'KMEANS Anomalies account_no = {accounts[7]} (outliers_fraction =
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
acc8_kmeans['anomaly_kmeans'] = acc8_kmeans_scaled['anomaly_kmeans']
df = acc8_kmeans.copy()
a= df.loc[df['anomaly_kmeans']==1, ['date', 'balance_amt']]
plt.figure(figsize=(20,8))
plt.plot(df['date'], df['balance_amt'], color='blue', label='Normal')
plt.scatter(a['date'], a['balance_amt'], color='red', label='Anomaly')
plt.title(f'{accounts[7]} Kmeans Distribution Anomalies')
plt.xlabel('Date')
plt.ylabel('balance_amt')
plt.legend()
plt.show()
```



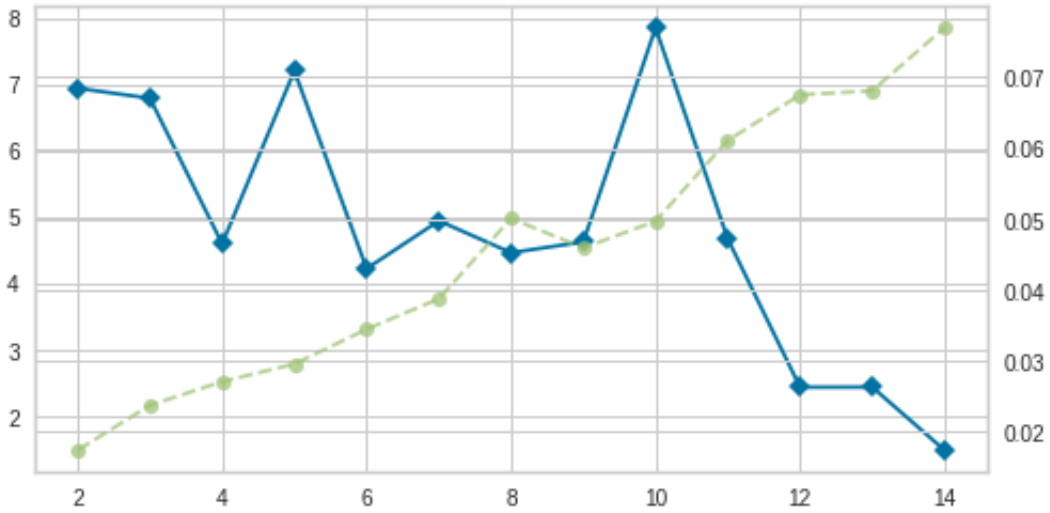
(IX) Customer account_no_409000425051

```
acc9_kmeans = acc9.copy()
scaler = StandardScaler()
acc9_kmeans_scaled = pd.DataFrame(scaler.fit_transform(acc9_kmeans[acc9.columns
acc9_kmeans_scaled.set_index(acc9_kmeans.index, drop=True, inplace=True)
acc9_kmeans_scaled.head(3)
```

	day_diff	weekend_date	weekend_value_date	withdrawal_amt	deposit_amt
2137	0.0	-0.429695	-0.429695	-0.038344	-0.02322
2138	0.0	-0.429695	-0.429695	-0.038344	-0.05979
2139	0.0	-0.429695	-0.429695	-0.038344	-0.02322

```
# Instantiate the clustering model and visualizer
visualizer = KElbowVisualizer(KMeans(), k=(2,15))
plt.figure(figsize=(8,4)).patch.set_facecolor('xkcd:white')
visualizer.fit(acc9_kmeans_scaled)       # Fit the data to the visualizer
# visualizer.show()        # Finalize and render the figure
```

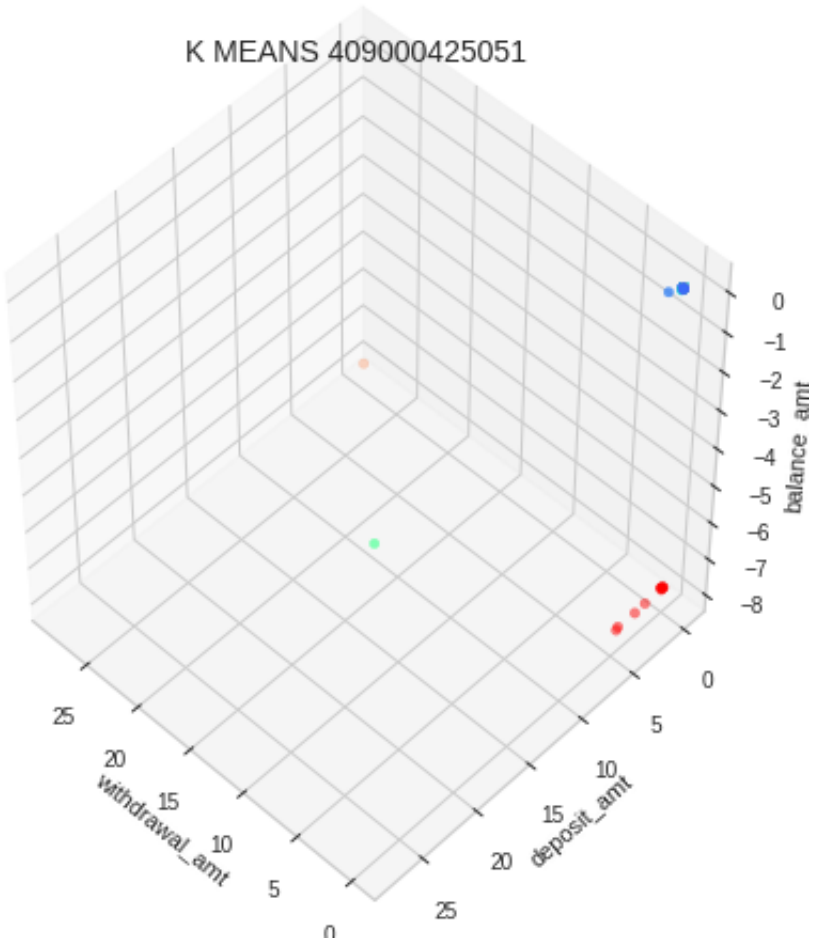
```
KElbowVisualizer(ax=<matplotlib.axes._subplots.AxesSubplot object at 0x7fa4
                 k=None, metric=None, model=None, timings=True)
```



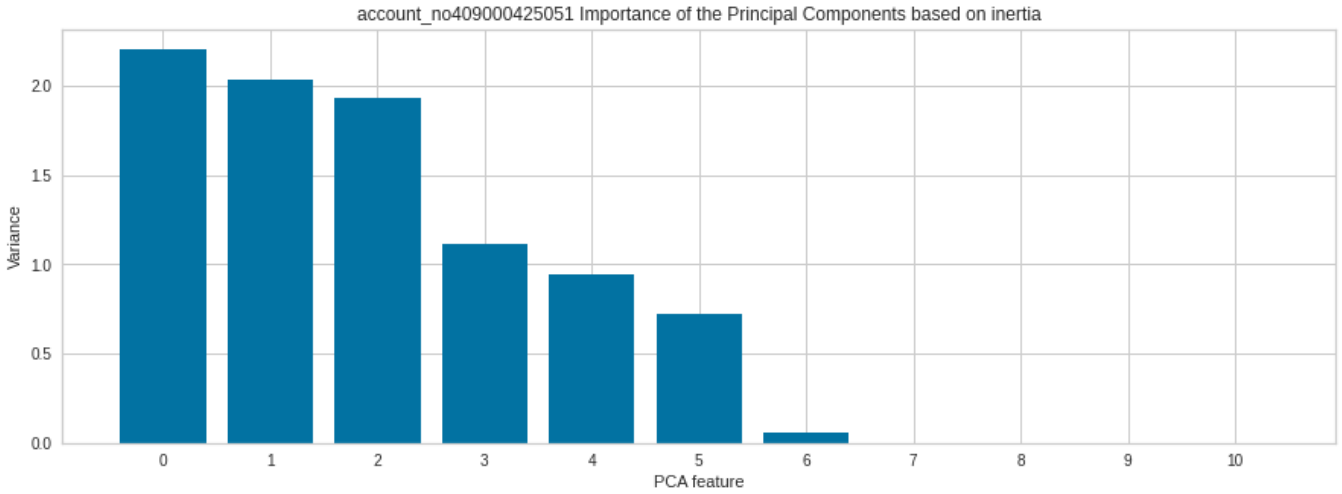

```
kmeans = KMeans(n_clusters=7)
kmeans.fit(acc9_kmeans_scaled)
labels = kmeans.labels_
```

```
fig = plt.figure(1, figsize=(6,6))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc9_kmeans_scaled.iloc[:,3], acc9_kmeans_scaled.iloc[:,4], acc9_km
ax.set_title(f'K MEANS {accounts[8]}', fontsize=14)
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
x = acc9_kmeans_scaled
pca = PCA()
pipeline = make_pipeline(pca)
pipeline.fit(x)
# Plot the principal components against their inertia
features = range(pca.n_components_)
_ = plt.figure(figsize=(15, 5))
_ = plt.bar(features, pca.explained_variance_)
_ = plt.xlabel('PCA feature')
_ = plt.ylabel('Variance')
_ = plt.xticks(features)
_ = plt.title(f"account_no{accounts[8]} Importance of the Principal Components
plt.show()
```




```
acc9_pca = pd.DataFrame(PCA(n_components=6).fit_transform(acc9_kmeans_scaled),
```

```
kmeans = KMeans(n_clusters=7)
kmeans.fit(acc9_pca)
labels = kmeans.predict(acc9_pca)

unique_elements, counts_elements = np.unique(labels, return_counts=True)
clusters = np.asarray((unique_elements, counts_elements))

outliers_fraction = 0.008
distance = getDistanceByPoint(acc9_pca, kmeans)

number_of_outliers = int(outliers_fraction*len(distance))
threshold = distance.nlargest(number_of_outliers).min()
acc9_pca['anomaly_kmeans'] = (distance >= threshold).astype(int)


acc9_pca.index = acc9.index
acc9_pca.anomaly_kmeans.value_counts()
```

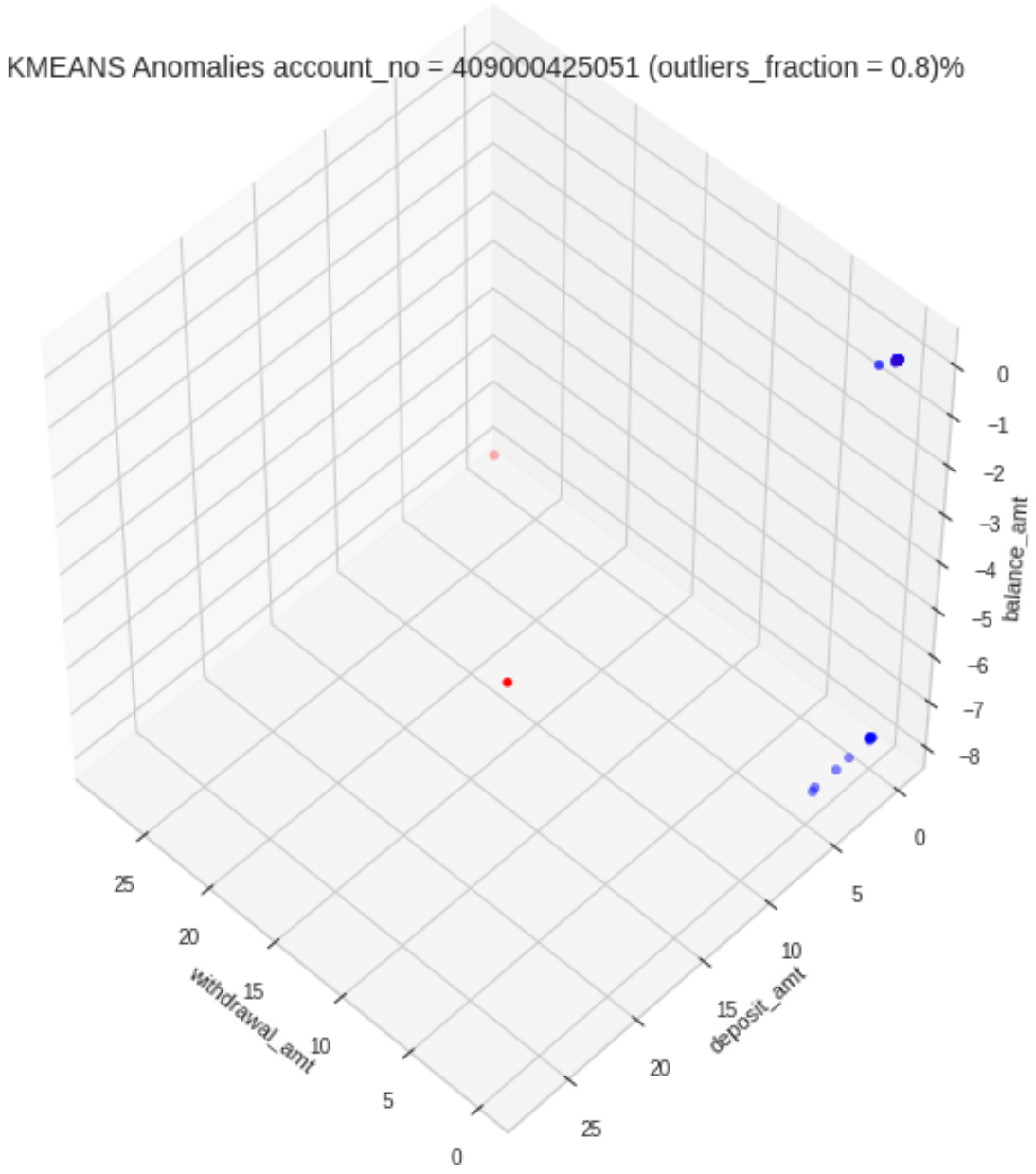
```
0    796
1      6
Name: anomaly_kmeans, dtype: int64
```

```
acc9_kmeans_scaled['anomaly_kmeans'] = acc9_pca.anomaly_kmeans
bank_main['km_9'] = 0
bank_main.loc[acc9_kmeans_scaled.index,'km_9'] = acc9_kmeans_scaled['anomaly_k
bank_main['km_9'].value_counts()
```

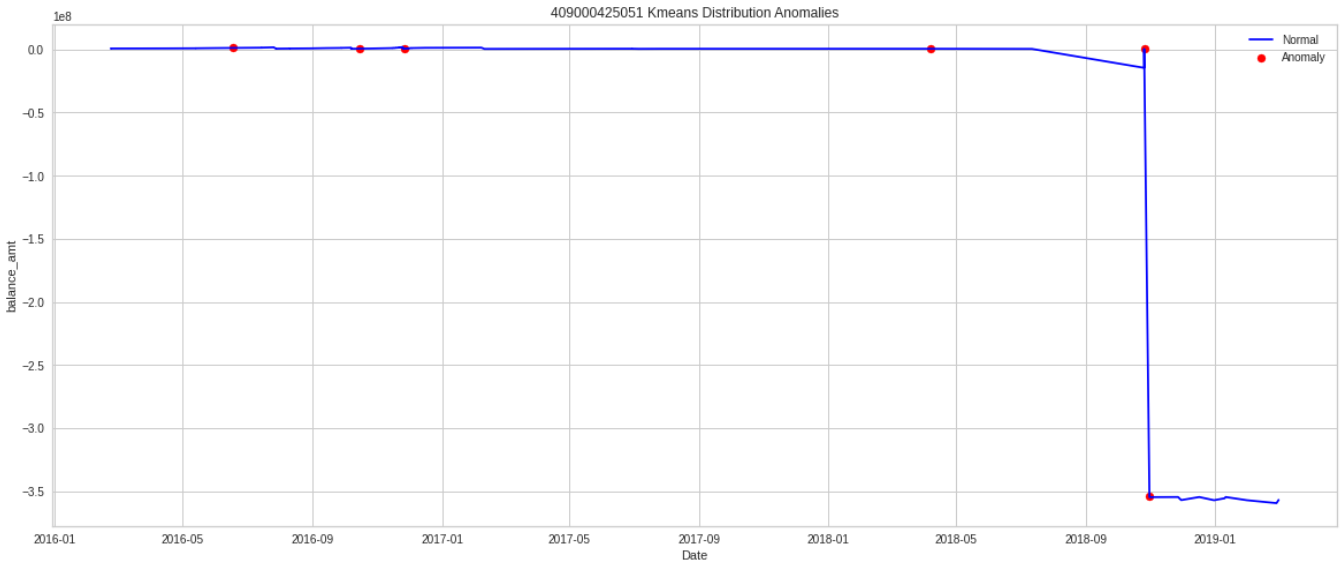
```
0    116195
1         6
Name: km_9, dtype: int64
```

```
labels = acc9_kmeans_scaled.anomaly_kmeans
colors = {0:'blue', 1:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc9_kmeans_scaled.iloc[:,3], acc9_kmeans_scaled.iloc[:,4], acc9_km
ax.set_title(f'KMEANS Anomalies account_no = {accounts[8]} (outliers_fraction =
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
acc9_kmeans['anomaly_kmeans'] = acc9_kmeans_scaled['anomaly_kmeans']
df = acc9_kmeans.copy()
a= df.loc[df['anomaly_kmeans']==1, ['date', 'balance_amt']]
plt.figure(figsize=(20,8))
plt.plot(df['date'], df['balance_amt'], color='blue', label='Normal')
plt.scatter(a['date'], a['balance_amt'], color='red', label='Anomaly')
plt.title(f'{accounts[8]} Kmeans Distribution Anomalies')
plt.xlabel('Date')
plt.ylabel('balance_amt')
plt.legend()
plt.show()
```



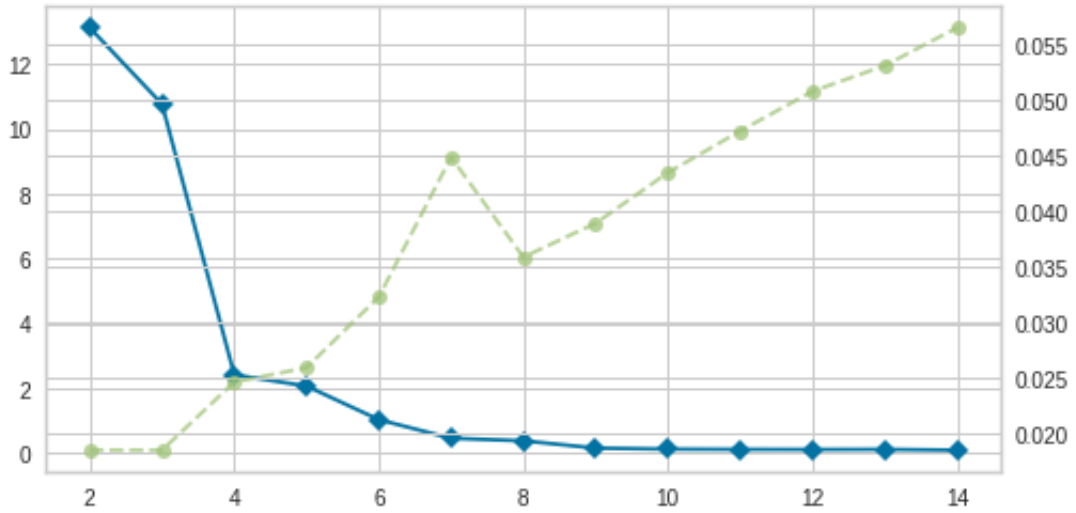
(X) Customer account_no_409000405747

```
acc10_kmeans = acc10.copy()
scaler = StandardScaler()
acc10_kmeans_scaled = pd.DataFrame(scaler.fit_transform(acc10_kmeans[acc10.colu
acc10_kmeans_scaled.set_index(acc10_kmeans.index, drop=True, inplace=True)
acc10_kmeans_scaled.head(3)
```

	day_diff	weekend_date	weekend_value_date	withdrawal_amt	deposit_am
2939	0.0	2.318405	2.318405	5.917619	-0.16033
2940	0.0	2.318405	2.318405	0.795991	-0.16033
2941	0.0	2.318405	2.318405	-0.296882	-0.16033

```
# Instantiate the clustering model and visualizer
visualizer = KElbowVisualizer(KMeans(), k=(2,15))
plt.figure(figsize=(8,4)).patch.set_facecolor('xkcd:white')
visualizer.fit(acc10_kmeans_scaled)       # Fit the data to the visualizer
# visualizer.show()        # Finalize and render the figure
```

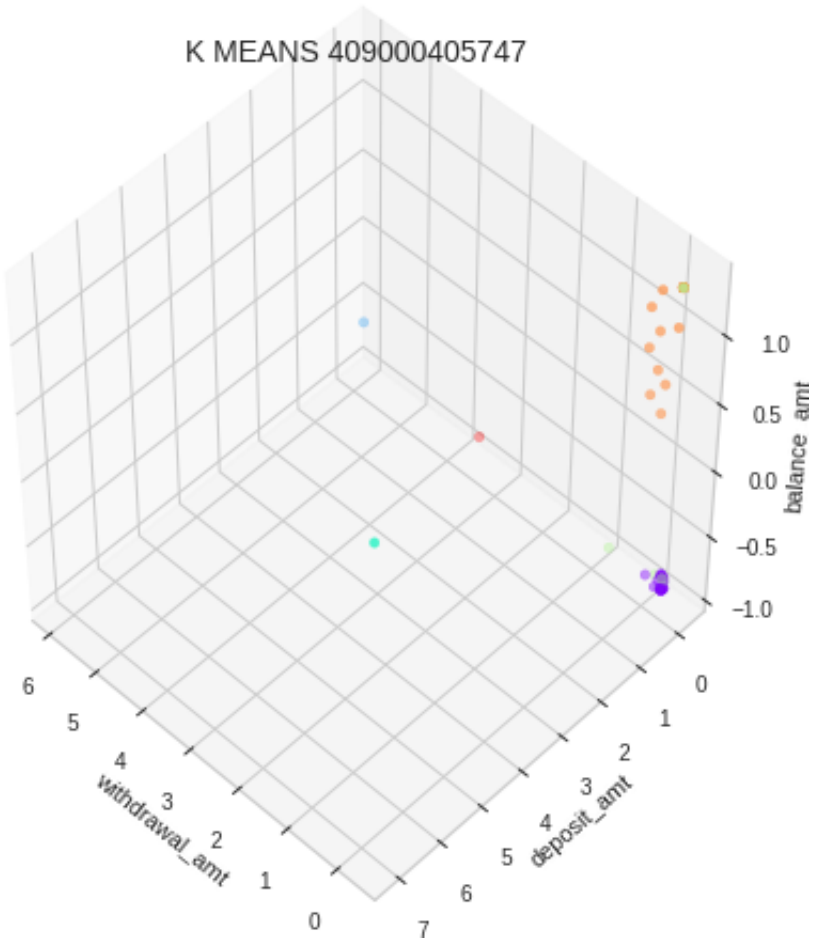
```
KElbowVisualizer(ax=<matplotlib.axes._subplots.AxesSubplot object at 0x7fa4
                 k=None, metric=None, model=None, timings=True)
```



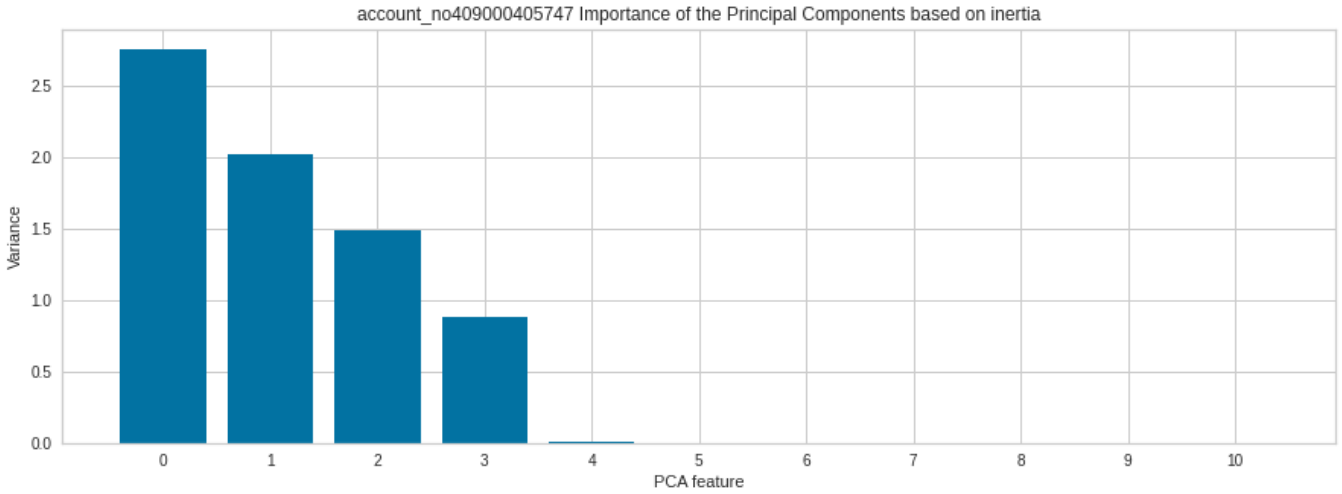

```
kmeans = KMeans(n_clusters=6)
kmeans.fit(acc10_kmeans_scaled)
labels = kmeans.labels_
```

```
fig = plt.figure(1, figsize=(6,6))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc10_kmeans_scaled.iloc[:,3], acc10_kmeans_scaled.iloc[:,4], acc10
ax.set_title(f'K MEANS {accounts[9]}', fontsize=14)
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
x = acc10_kmeans_scaled
pca = PCA()
pipeline = make_pipeline(pca)
pipeline.fit(x)
# Plot the principal components against their inertia
features = range(pca.n_components_)
_ = plt.figure(figsize=(15, 5))
_ = plt.bar(features, pca.explained_variance_)
_ = plt.xlabel('PCA feature')
_ = plt.ylabel('Variance')
_ = plt.xticks(features)
_ = plt.title(f"account_no{accounts[9]} Importance of the Principal Components
plt.show()
```




```
acc10_pca = pd.DataFrame(PCA(n_components=3).fit_transform(acc10_kmeans_scaled)
```

```
kmeans = KMeans(n_clusters=4)
kmeans.fit(acc10_pca)
labels = kmeans.predict(acc10_pca)

unique_elements, counts_elements = np.unique(labels, return_counts=True)
clusters = np.asarray((unique_elements, counts_elements))

outliers_fraction = 0.1
distance = getDistanceByPoint(acc10_pca, kmeans)

number_of_outliers = int(outliers_fraction*len(distance))
threshold = distance.nlargest(number_of_outliers).min()
acc10_pca['anomaly_kmeans'] = (distance >= threshold).astype(int)


acc10_pca.index = acc10.index
acc10_pca.anomaly_kmeans.value_counts()
```

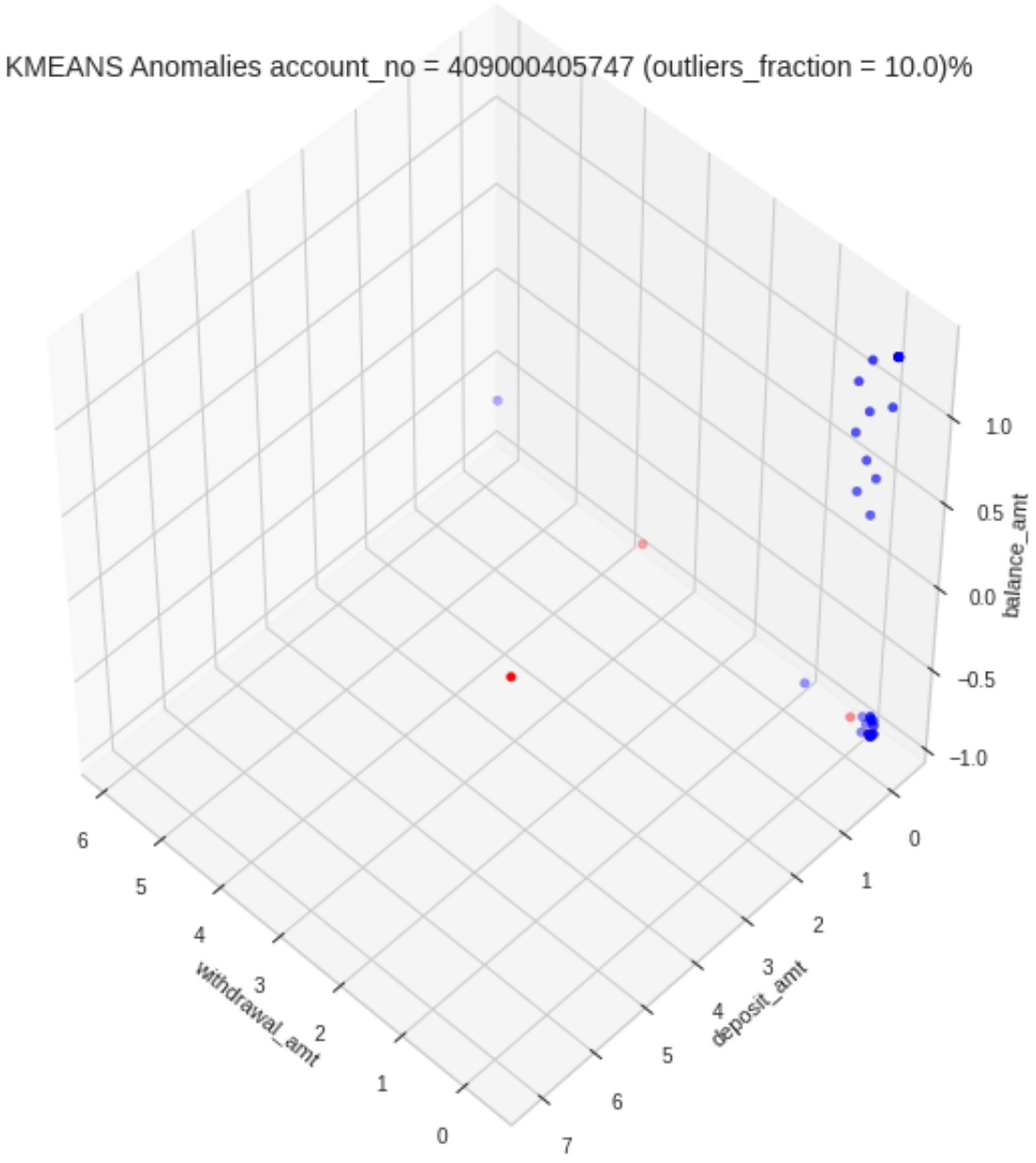
```
0    46
1     5
Name: anomaly_kmeans, dtype: int64
```

```
acc10_kmeans_scaled['anomaly_kmeans'] = acc10_pca.anomaly_kmeans
bank_main['km_10'] = 0
bank_main.loc[acc10_kmeans_scaled.index,'km_10'] = acc10_kmeans_scaled['anomaly
bank_main['km_10'].value_counts()
```

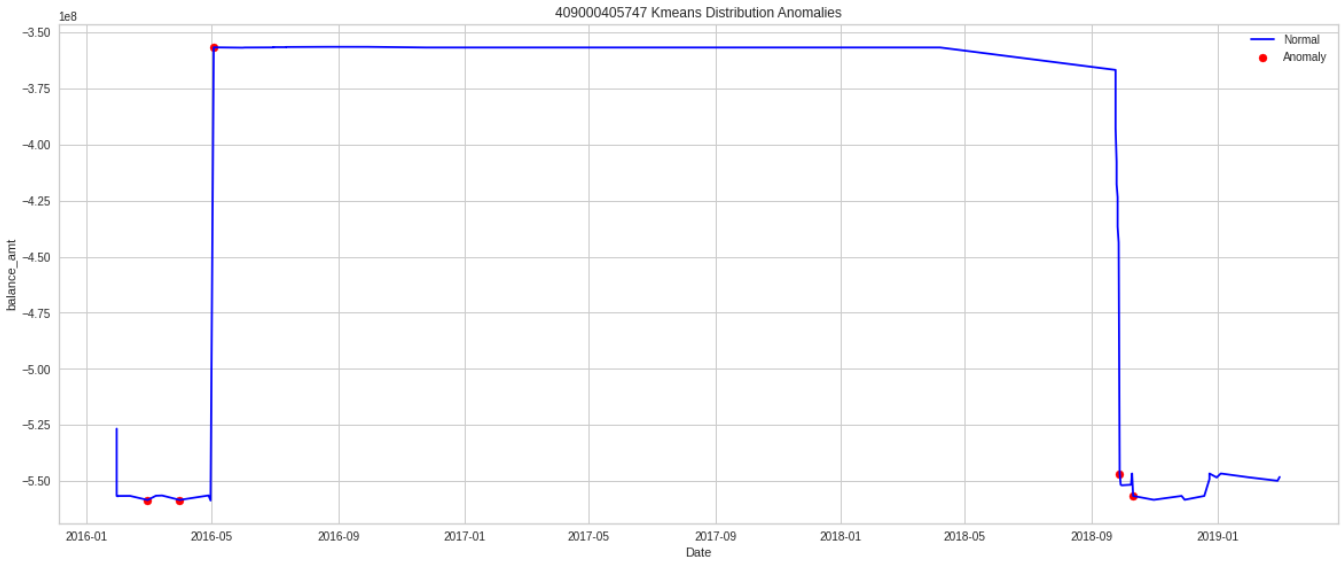
```
0    116196
1         5
Name: km_10, dtype: int64
```

```
labels = acc10_kmeans_scaled.anomaly_kmeans
colors = {0:'blue', 1:'red'}

fig = plt.figure(1, figsize=(8,8))
ax = Axes3D(fig, rect=[0, 0, .95, 1], elev=48, azim=134)
ax.scatter(acc10_kmeans_scaled.iloc[:,3], acc10_kmeans_scaled.iloc[:,4], acc10
ax.set_title(f'KMEANS Anomalies account_no = {accounts[9]} (outliers_fraction =
ax.set_xlabel('withdrawal_amt')
ax.set_ylabel('deposit_amt')
ax.set_zlabel('balance_amt')
```

```
Text(0.5, 0, 'balance_amt')
```



```
acc10_kmeans['anomaly_kmeans'] = acc10_kmeans_scaled['anomaly_kmeans']
df = acc10_kmeans.copy()
a= df.loc[df['anomaly_kmeans']==1, ['date', 'balance_amt']]
plt.figure(figsize=(20,8))
plt.plot(df['date'], df['balance_amt'], color='blue', label='Normal')
plt.scatter(a['date'], a['balance_amt'], color='red', label='Anomaly')
plt.title(f'{accounts[9]} Kmeans Distribution Anomalies')
plt.xlabel('Date')
plt.ylabel('balance_amt')
plt.legend()
plt.show()
```




```
bank_main['accounts_kmeans'] = bank_main.km_1 + bank_main.km_2 + bank_main.km_
```

```
bank_main['accounts_kmeans'].value_counts()
```

```
0    115794
1       407
Name: accounts_kmeans, dtype: int64
```

```
bank_main['anomaly_sum_2'] = bank_main.accounts_isolation_forest + bank_main.a
```

5. Grading Anomalies

```
bank_graded = bank_main.copy()
```

```
drop_lst =['iso_1', 'iso_2', 'iso_3', 'iso_4', 'iso_5', 'iso_6', 'iso_7', 'iso
 'svm_1', 'svm_2', 'svm_3', 'svm_4', 'svm_5', 'svm_6', 'svm_7', 'svm_8', 'svm_
 'gauss_10', 'gauss_2', 'gauss_1', 'gauss_3', 'gauss_4', 'gauss_5', 'gauss_6',
 'km_1', 'km_2', 'km_3', 'km_4', 'km_5', 'km_6', 'km_7', 'km_8', 'km_9', 'km_1

bank_graded.drop(columns=drop_lst, axis=1, inplace=True)
```

```
bank_graded['weighted_anomaly'] = bank_graded.anomaly_sum_1 + 2 * bank_graded.
bank_graded['weighted_anomaly'].value_counts()
```

```
0     113340
2       1202
1        774
3        323
4        233
6         96
5         72
7         67
8         53
9         17
10        14
11        10
Name: weighted_anomaly, dtype: int64
```

```
bank_graded['ranks'] =  0
```

```
bank_graded.loc[bank_graded.weighted_anomaly>8, 'ranks'] = 1
bank_graded.loc[(bank_graded.weighted_anomaly>4) & (bank_graded.weighted_anoma
bank_graded.loc[(bank_graded.weighted_anomaly>2) & (bank_graded.weighted_anoma
bank_graded.ranks.value_counts()
```

```
0    115316
3       556
2       288
1        41
Name: ranks, dtype: int64
```

Since we have essentially determined **weighted_anomaly** using machine learning algorithms, we now want to check some suspicious points that we discovered during the EDA phase. And finally, we synthesize a rank value for each instance.

day_diff vs. weighted_anomaly

```
bank_graded[bank_graded.day_diff<0][['day_diff', 'weighted_anomaly', 'ranks']]
```

	day_diff	weighted_anomaly	ranks
63340	-1	5	2

```
bank_graded.loc[bank_graded.day_diff<0, 'ranks'] = 1
```

```
bank_graded[bank_graded.day_diff>4][['day_diff', 'weighted_anomaly', 'ranks']]
```

	day_diff	weighted_anomaly	ranks
36647	5	4	3
36648	5	2	0
36727	5	4	3
36728	5	2	0
36892	5	4	3
36893	5	2	0
36894	5	4	3
36915	5	2	0
36916	5	4	3
63717	6	6	2
103332	29	6	2
103335	29	6	2
104111	8	6	2
112081	18	6	2

```
bank_graded.loc[(bank_graded.day_diff>4) & (bank_graded.day_diff<6) & (bank_gra
bank_graded.loc[bank_graded.day_diff>10, 'ranks'] = 1
```

```
bank_graded[bank_graded.day_diff>4].ranks.value_counts()
```

```
3    9
1    3
2    2
Name: ranks, dtype: int64
```

details_null_penalty vs. weighted_anomaly

```
bank_graded[bank_graded.details_null_penalty>0][['details_null_penalty', 'weigh
```

	details_null_penalty	weighted_anomaly	ranks
30345	1	1	0
30346	1	3	3
30584	1	6	2
30585	1	6	2
31192	1	1	0
...	...	...	...
97686	1	0	0
97687	1	0	0
97781	1	0	0
97782	1	0	0
97783	1	0	0

2499 rows × 3 columns

```
bank_graded[bank_graded.details_null_penalty>0].ranks.value_counts()
```

```
0    2359
3     131
2       9
Name: ranks, dtype: int64
```

weekend_date vs. weighted_anomaly

```
bank_graded[bank_graded.weekend_date>0][['weekend_date', 'weekend_value_date',
```

	weekend_date	weekend_value_date	weighted_anomaly	ranks
117	1	1	4	3
118	1	1	0	0
119	1	1	0	0
120	1	1	0	0
153	1	1	1	0
...	...	...	...	...
116167	1	1	0	0
116168	1	1	0	0
116169	1	1	0	0
116170	1	1	0	0
116171	1	1	0	0

10053 rows × 4 columns

```
bank_graded[bank_graded.weekend_date>0].ranks.value_counts()
```

```
0    9693
3     270
2      81
1       9
Name: ranks, dtype: int64
```

```
bank_graded[bank_graded.weekend_date + bank_graded.weekend_value_date==1][['we
```

	weekend_date	weekend_value_date	weighted_anomaly	ranks
32528	0	1	1	0
34732	0	1	1	0
35192	0	1	9	1
35798	0	1	1	0
37011	0	1	1	0
37221	1	0	2	0
37222	1	0	7	2
41340	0	1	5	2
54062	0	1	4	3
91948	0	1	4	3
104139	1	0	2	0
104159	1	0	0	0
110119	1	0	2	0
113157	1	0	2	0

```
bank_graded.loc[(bank_graded.weekend_date + bank_graded.weekend_value_date==1)
```

```
bank_graded[bank_graded.weekend_date + bank_graded.weekend_value_date==1].rank
```

```
3    7
0    4
2    2
1    1
Name: ranks, dtype: int64
```

cheque_penalty vs. weighted_anomaly

```
bank_graded[bank_graded.cheque_penalty>0][['cheque_penalty', 'weighted_anomaly
```

	cheque_penalty	weighted_anomaly	ranks
2907	1	2	0
2908	1	2	0
2909	1	2	0
2910	1	2	0
2911	1	2	0
2912	1	2	0
2913	1	2	0
2914	1	2	0
2915	1	2	0
5654	1	6	2
5967	1	6	2
6227	1	6	2
6229	1	6	2
22174	1	4	3
22176	1	4	3
22178	1	4	3
22208	1	4	3
22210	1	4	3
22220	1	4	3
22245	1	4	3
22247	1	4	3

```
bank_graded[bank_graded.cheque_penalty>0].ranks.value_counts()
```

```
0    9
3    8
2    4
Name: ranks, dtype: int64
```

```
bank_graded.ranks.value_counts()
```

```
0    115307
3       565
2       284
1        45
Name: ranks, dtype: int64
```

6. Conclusion

```
bank_ranked = bank_graded.copy()
```

```
drop_lst = ['account_no_1196428', 'account_no_1196711', 'account_no_4090003624
            'account_no_409000438611', 'account_no_409000438620', 'account_no_
            'anomaly_kmeans', 'anomaly_isolation_forest', 'anomaly_one_class_s
            'accounts_isolation_forest', 'accounts_SVM', 'accounts_gaussian_di
```

```
bank_ranked.drop(columns=drop_lst, axis=1, inplace=True)
```

```
bank_ranked['account_no'] = bank_premodel.account_no
```

```
bank_ranked.head()
```

	date	value_date	day_diff	weekend_date	weekend_value_date	withdrawal_
0	2017-06-29	2017-06-29	0	0	0	
1	2017-07-05	2017-07-05	0	0	0	
2	2017-07-18	2017-07-18	0	0	0	
3	2017-08-01	2017-08-01	0	0	0	
4	2017-08-16	2017-08-16	0	0	0	

```
bank_ranked.to_excel('bank_transaction_ranked.xlsx')
```

```
bank_ranked[bank_ranked.deposit_over_balance < 0].ranks.value_counts()
```

```
0    60646
3      289
2      145
1       21
Name: ranks, dtype: int64
```

✓ 0s completed at 11:03 PM