Credibility Classification of Credit Card Clients

Group information:

Team number: 13

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Link to source

1. Start by loading the necessary packages and training data set.

In [1]:
```
import pandas as pd
import altair as alt
from pandas_profiling import ProfileReport
from altair_data_server import data_server

# Save a vega-lite spec and a PNG blob for each plot in the notebook
alt.renderers.enable('mimetype')
# Handle large data sets without embedding them in the notebook
alt.data_transformers.enable('data_server')
```

Out[1]:
```
DataTransformerRegistry.enable('data_server')
```

In [2]:
```
headernames = [
    "ID",
    "LIMIT_BAL",
    "SEX",
    "EDUCATION",
    "MARRIAGE",
    "AGE",
    "PAY_0",
    "PAY_2",
    "PAY_3",
    "PAY_4",
    "PAY_5",
    "PAY_6",
    "BILL_AMT1",
    "BILL_AMT2",
    "BILL_AMT3",
    "BILL_AMT4",
    "BILL_AMT5",
    "BILL_AMT6",
    "PAY_AMT1",
    "PAY_AMT2",
    "PAY_AMT3",
    "PAY_AMT4",
    "PAY_AMT5",
    "PAY_AMT6",
    "default payment next month",
]
train_df = pd.read_csv("../data/split/train.csv", index_col=0, skiprows=1, names=headern
test_df = pd.read_csv("../data/split/test.csv", index_col=0, skiprows=1, names=headernam
```

2. Basic Exploratory Data Analysis (EDA).

Looking at the first and last rows of the training data.

In [3]:
```
train_df.head()
```

Out[3]:

	ID	LIMIT_BAL	SEX	EDUCATION	MARRIAGE	AGE	PAY_0	PAY_2	PAY_3	PAY_4	...	BILL_AI
23637	23638	200000	2	2	2	46	0	0	0	0	...	136
17169	17170	50000	2	3	2	26	0	0	0	0	...	26
15955	15956	210000	2	1	2	30	0	0	0	0	...	5
21486	21487	90000	2	1	2	27	0	0	2	0	...	50
12211	12212	60000	1	2	1	40	0	0	0	0	...	22

5 rows × 25 columns

In [4]:
```
train_df.tail()
```

Out[4]:

	ID	LIMIT_BAL	SEX	EDUCATION	MARRIAGE	AGE	PAY_0	PAY_2	PAY_3	PAY_4	...	BILL_AI
4426	4427	110000	2	2	1	28	0	0	0	0	...	45
12695	12696	20000	2	3	2	38	-1	-1	2	0	...	3
3360	3361	150000	2	2	1	42	0	0	0	0	...	138
18283	18284	190000	1	1	1	54	0	0	0	0	...	192
28564	28565	100000	2	1	1	36	-2	-2	-2	-2	...	15

5 rows × 25 columns

There are 24000 records in the training data set and no missing values in any rows or columns.

In [5]:
```
train_df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 24000 entries, 23637 to 28564
Data columns (total 25 columns):
 #   Column                      Non-Null Count  Dtype
---  ------                      --------------  -----
 0   ID                          24000 non-null  int64
 1   LIMIT_BAL                   24000 non-null  int64
 2   SEX                         24000 non-null  int64
 3   EDUCATION                   24000 non-null  int64
 4   MARRIAGE                    24000 non-null  int64
 5   AGE                         24000 non-null  int64
 6   PAY_0                       24000 non-null  int64
 7   PAY_2                       24000 non-null  int64
 8   PAY_3                       24000 non-null  int64
 9   PAY_4                       24000 non-null  int64
 10  PAY_5                       24000 non-null  int64
 11  PAY_6                       24000 non-null  int64
 12  BILL_AMT1                   24000 non-null  int64
 13  BILL_AMT2                   24000 non-null  int64
 14  BILL_AMT3                   24000 non-null  int64
 15  BILL_AMT4                   24000 non-null  int64
 16  BILL_AMT5                   24000 non-null  int64
 17  BILL_AMT6                   24000 non-null  int64
 18  PAY_AMT1                    24000 non-null  int64
 19  PAY_AMT2                    24000 non-null  int64
 20  PAY_AMT3                    24000 non-null  int64
 21  PAY_AMT4                    24000 non-null  int64
 22  PAY_AMT5                    24000 non-null  int64
 23  PAY_AMT6                    24000 non-null  int64
 24  default payment next month  24000 non-null  int64
dtypes: int64(25)
memory usage: 4.8 MB
```

We have a binary feature, a few categorical features, and numerical features.

In [6]:
```
train_df.describe()
```

Out[6]:

	ID	LIMIT_BAL	SEX	EDUCATION	MARRIAGE	AGE	
count	24000.000000	24000.000000	24000.000000	24000.000000	24000.000000	24000.000000	24000.(
mean	15012.940792	167338.833333	1.602542	1.850875	1.551208	35.516833	-0.(
std	8649.751001	129933.404625	0.489382	0.788139	0.521430	9.216367	1.:
min	1.000000	10000.000000	1.000000	0.000000	0.000000	21.000000	-2.(
25%	7529.750000	50000.000000	1.000000	1.000000	1.000000	28.000000	-1.(
50%	15014.500000	140000.000000	2.000000	2.000000	2.000000	34.000000	0.(
75%	22476.250000	240000.000000	2.000000	2.000000	2.000000	41.000000	0.(
max	29999.000000	800000.000000	2.000000	6.000000	3.000000	79.000000	8.(

8 rows × 25 columns

3. Group features based on their types and make plots for each type.

In [7]:
```
train_df.columns.tolist()
```

Out[7]:
```
['ID',
 'LIMIT_BAL',
 'SEX',
 'EDUCATION',
 'MARRIAGE',
 'AGE',
 'PAY_0',
 'PAY_2',
 'PAY_3',
 'PAY_4',
 'PAY_5',
 'PAY_6',
 'BILL_AMT1',
 'BILL_AMT2',
 'BILL_AMT3',
 'BILL_AMT4',
 'BILL_AMT5',
 'BILL_AMT6',
 'PAY_AMT1',
 'PAY_AMT2',
 'PAY_AMT3',
 'PAY_AMT4',
 'PAY_AMT5',
 'PAY_AMT6',
 'default payment next month']
```

In [8]:
```
categorical_features = [
    "EDUCATION",
    "MARRIAGE",
    "PAY_0",
    "PAY_2",
    "PAY_3",
    "PAY_4",
    "PAY_5",
    "PAY_6",
]

binary_features = ["SEX"]

drop = ["ID", "default payment next month"]

numeric_features = [
    "LIMIT_BAL",
    "AGE",
    "BILL_AMT1",
    "BILL_AMT2",
    "BILL_AMT3",
    "BILL_AMT4",
    "BILL_AMT5",
    "BILL_AMT6",
    "PAY_AMT1",
    "PAY_AMT2",
    "PAY_AMT3",
    "PAY_AMT4",
    "PAY_AMT5",
    "PAY_AMT6",
]
```

Categorical features

`Education` : Ordinal feature. 1 = graduate school; 2 = university; 3 = high school; 4 = others.
`Marital status` : 1 = married; 2 = single; 3 = others.
`PAY_X` : Ordinal feature. The history of monthly payment tracked from April to September, 2005, as follows: PAY_1 = the repayment status in September, 2005; PAY_2 = the repayment status in August, 2005; . . .;PAY_6 = the repayment status in April, 2005. The measurement scale for the repayment status is: -1 = pay duly; 1 = payment delay for one month; 2 = payment delay for two months; . . .; 8 = payment delay for eight months; 9 = payment delay for nine months and above.

Binary features

`Sex` is reported as a binary feature (1 = male; 2 = female).

Drop

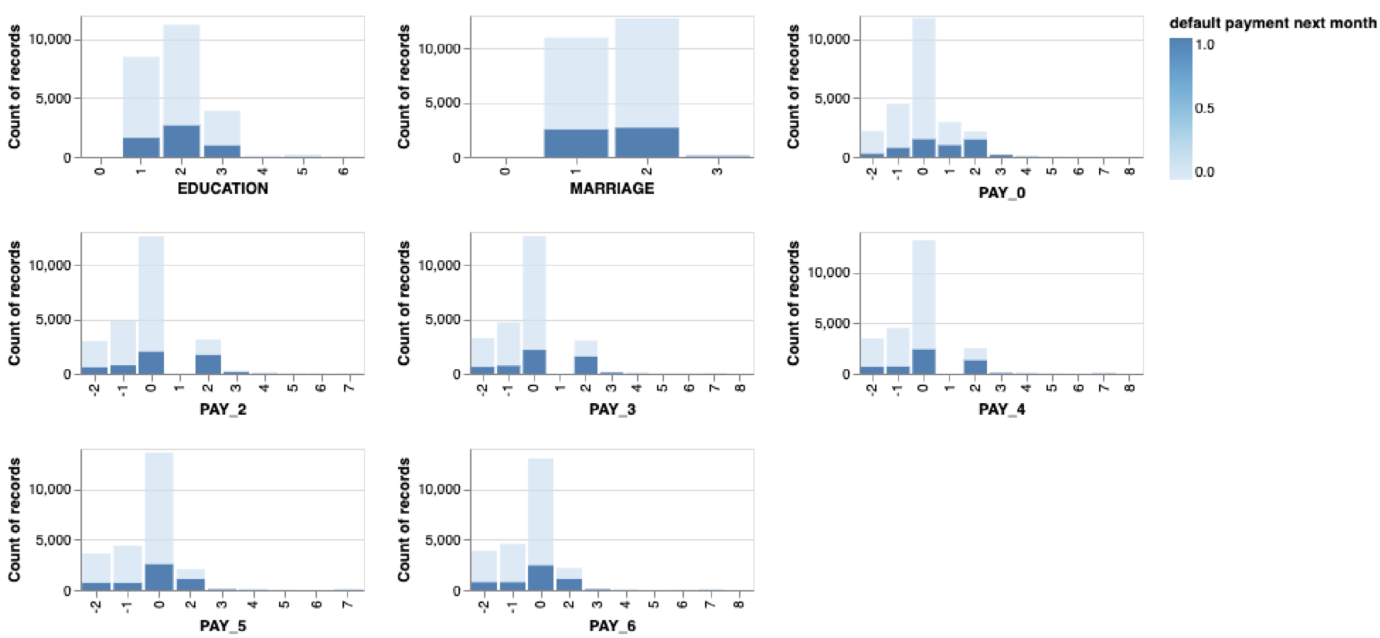
`ID` duplicate column from the index. `default payment next month` is the target column.

Numeric features

`LIMIT_BAL` : The amount of the given credit (NT dollar): it includes both the individual consumer credit and his/her family (supplementary) credit.
`Age` : The age of the individual (years).
`BILL_AMTX` : Amount of bill statement (NT dollar). BILL_AMT1 = amount of bill statement in September, 2005; BILL_AMT2 = amount of bill statement in August, 2005; . . .; BILL_AMT6 = amount of bill statement in April, 2005.
`PAY_AMTX` : Amount of previous payment (NT dollar). PAY_AMT1 = amount paid in September, 2005; PAY_AMT2 = amount paid in August, 2005; . . .;PAY_AMT6 = amount paid in April, 2005.

In [9]:
```
# Plotting categorical features
alt.Chart(train_df).mark_bar(opacity=0.7).encode(
    y=alt.Y("count()", title="Count of records"),
    x=alt.X(alt.repeat()),
    color=alt.Color("default payment next month"),
).properties(width=200, height=100).repeat(categorical_features, columns=3)
```

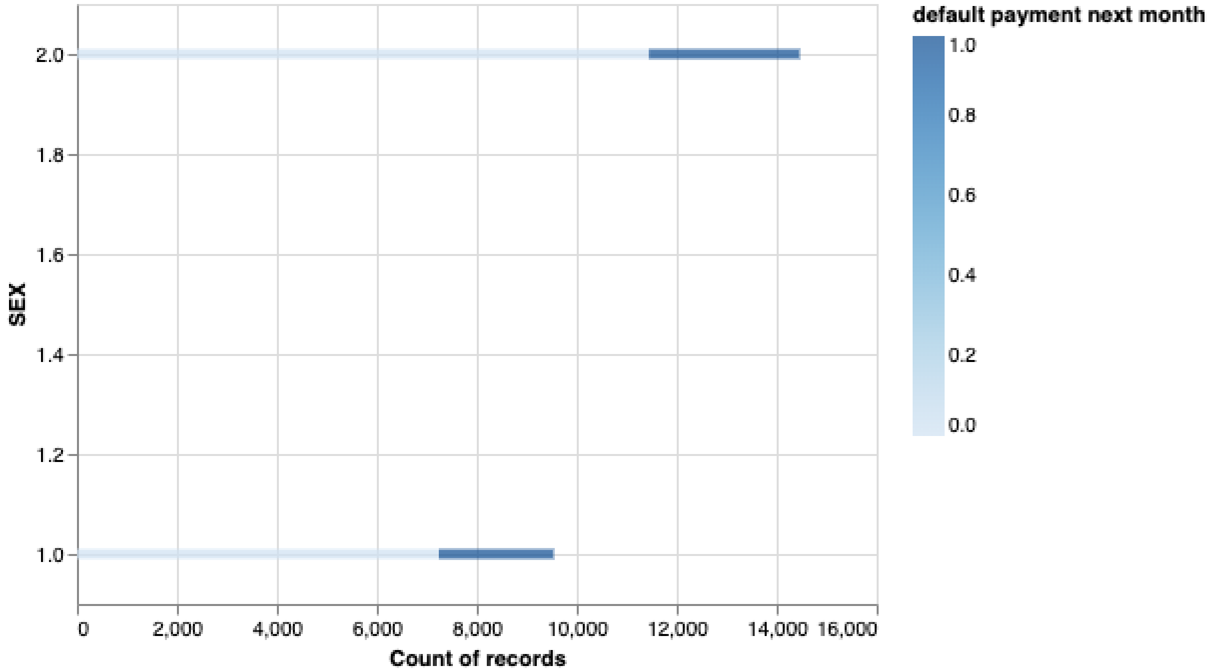
Out[9]:



In [10]:
```
# Plotting the binary feature.
alt.Chart(train_df).mark_bar(opacity=0.7).encode(
    x=alt.X("count()", title="Count of records"),
```

```
    y=alt.Y("SEX", title="SEX"),
    color=alt.Color("default payment next month"),
)
```

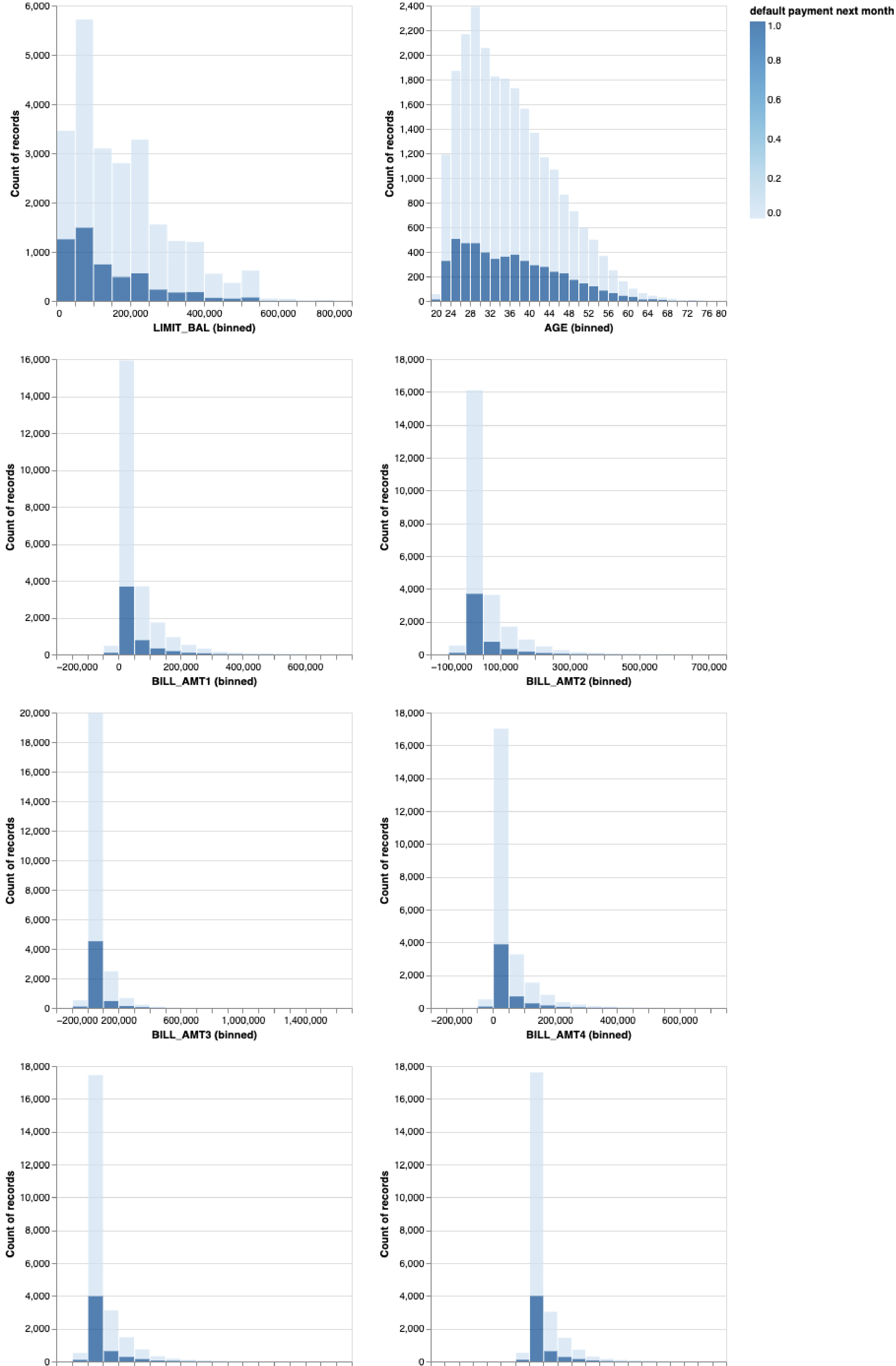
Out[10]:

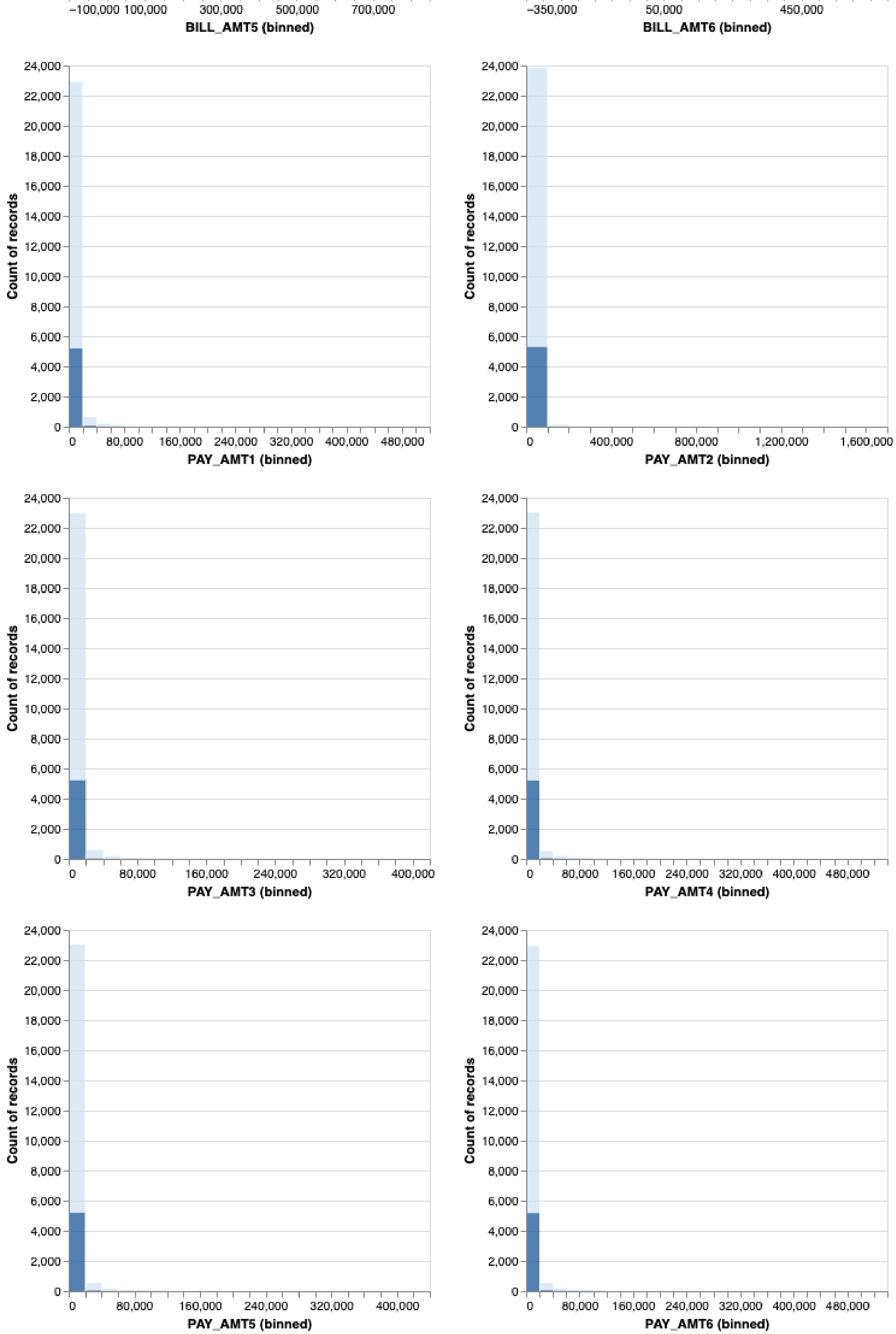


In [11]:

```
# Plotting numeric features.
alt.Chart(train_df).mark_bar(opacity=0.7).encode(
    x=alt.X(alt.repeat(), bin=alt.Bin(maxbins=30)),
    y=alt.Y("count()", title="Count of records"),
    color=alt.Color("default payment next month")
).properties(width=300, height=300).repeat(numeric_features, columns=2)
```

Out[11]:


default payment next month
1.0
0.8
0.6
0.4
0.2
0.0
Count of records
LIMIT_BAL (binned)
AGE (binned)
BILL_AMT1 (binned)
BILL_AMT2 (binned)
BILL_AMT3 (binned)
BILL_AMT4 (binned)



4. Looking at the correlation of the features.

In [12]:
```
# Correlation matrix
train_df.corr('spearman').style.background_gradient()
```

Out[12]:

	ID	LIMIT_BAL	SEX	EDUCATION	MARRIAGE	AGE	PAY_0	PAY_2
ID	1.000000	0.028541	0.019320	0.031970	-0.028712	0.025919	-0.021654	-0.002466
LIMIT_BAL	0.028541	1.000000	0.060286	-0.268328	-0.116244	0.187593	-0.297649	-0.342895
SEX	0.019320	0.060286	1.000000	0.018090	-0.031035	-0.093944	-0.057764	-0.080323
EDUCATION	0.031970	-0.268328	0.018090	1.000000	-0.159241	0.155942	0.134109	0.172066
MARRIAGE	-0.028712	-0.116244	-0.031035	-0.159241	1.000000	-0.465114	0.024195	0.044070
AGE	0.025919	0.187593	-0.093944	0.155942	-0.465114	1.000000	-0.069612	-0.089557
PAY_0	-0.021654	-0.297649	-0.057764	0.134109	0.024195	-0.069612	1.000000	0.629202
PAY_2	-0.002466	-0.342895	-0.080323	0.172066	0.044070	-0.089557	0.629202	1.000000
PAY_3	-0.006918	-0.332193	-0.073374	0.164510	0.047767	-0.086708	0.547767	0.797501
PAY_4	-0.000462	-0.307932	-0.065007	0.154916	0.045280	-0.082754	0.515359	0.711599
PAY_5	-0.013630	-0.282368	-0.055901	0.139180	0.049074	-0.085413	0.483787	0.672817
PAY_6	-0.004005	-0.260386	-0.048387	0.122171	0.045070	-0.077506	0.461314	0.631828
BILL_AMT1	0.015631	0.057878	-0.047258	0.093723	0.008447	0.000556	0.311954	0.571351
BILL_AMT2	0.013779	0.054021	-0.046372	0.091435	0.009793	0.002127	0.327092	0.549666
BILL_AMT3	0.019907	0.064744	-0.035749	0.081583	0.004113	0.003077	0.311171	0.515023
BILL_AMT4	0.035288	0.077538	-0.025393	0.068140	0.006408	-0.001428	0.304766	0.494483
BILL_AMT5	0.017408	0.085668	-0.017615	0.058647	0.005600	-0.001636	0.297252	0.476306
BILL_AMT6	0.022651	0.092636	-0.014401	0.053934	0.007576	-0.002938	0.288727	0.458399
PAY_AMT1	0.016291	0.277853	-0.007549	-0.046449	-0.002548	0.035305	-0.104575	0.016063
PAY_AMT2	0.057308	0.284319	0.004275	-0.047695	-0.018691	0.045740	-0.068971	0.077223
PAY_AMT3	0.093810	0.291616	0.020041	-0.046964	-0.010725	0.034250	-0.060211	0.081213
PAY_AMT4	0.020003	0.287111	0.012868	-0.046198	-0.015711	0.039959	-0.038761	0.092237
PAY_AMT5	0.013567	0.299269	0.012915	-0.050315	-0.010087	0.035469	-0.028638	0.096236
PAY_AMT6	0.043229	0.319446	0.032551	-0.053385	-0.017300	0.037594	-0.045390	0.082007
default payment next month	-0.011783	-0.171828	-0.038160	0.046859	-0.021446	0.000687	0.294860	0.211601

5. EDA with Pandas Profiling package.

In [13]:
```
#profile = ProfileReport(train_df, title="Pandas Profiling Report")  # , minimal=True)
#profile.to_notebook_iframe()
```

SECTION 2: Preprocessing and Model selection

In [23]:
```
train_df["PAY_0"].value_counts()
```

Out[23]:
```
 0    11798
-1     4529
 1     2951
-2     2192
 2     2156
 3      267
 4       57
 5       20
 8       14
 6        8
 7        8
Name: PAY_0, dtype: int64
```

In [14]:
```python
# 1. Create the column transformer / preprocessor
# Imports
from sklearn.compose import ColumnTransformer, make_column_transformer
from sklearn.pipeline import Pipeline, make_pipeline
from sklearn.preprocessing import OneHotEncoder, StandardScaler, OrdinalEncoder

numeric_features = [
    "LIMIT_BAL",
    "AGE",
    "BILL_AMT1",
    "BILL_AMT2",
    "BILL_AMT3",
    "BILL_AMT4",
    "BILL_AMT5",
    "BILL_AMT6",
    "PAY_AMT1",
    "PAY_AMT2",
    "PAY_AMT3",
    "PAY_AMT4",
    "PAY_AMT5",
    "PAY_AMT6",
]

binary_features = ["SEX"]

drop = ["ID"]

ordinal_features = [
    "EDUCATION",
    "MARRIAGE",
    "PAY_0",
    "PAY_2",
    "PAY_3",
    "PAY_4",
    "PAY_5",
    "PAY_6",
]

# Create the column transformer
preprocessor = make_column_transformer(
    (StandardScaler(), numeric_features),
    (
        OrdinalEncoder(),
        ordinal_features,
    ),
    (
        OneHotEncoder(drop="if_binary", handle_unknown="ignore", sparse=False),
        binary_features,
```

```
    ),
    ("drop", drop),
)

# Show the preprocessor
preprocessor
```

Out[14]:

```
ColumnTransformer
standardscaler    ordinalencoder    onehotencoder    drop
StandardScaler    OrdinalEncoder    OneHotEncoder    drop
```

In [15]:

```
# 2. Fit and transform on the training data
X_train = train_df.drop(columns=["default payment next month"])
X_test = test_df.drop(columns=["default payment next month"])
y_train = train_df["default payment next month"]
y_test = test_df["default payment next month"]

# This line nicely formats the feature names from `preprocessor.get_feature_names_out()`
# so that we can more easily use them below
preprocessor.verbose_feature_names_out = False
# Create a dataframe with the transformed features and column names
preprocessor.fit(X_train)

# transformed data
X_train_transformed = preprocessor.transform(X_train)
ordinal_enc_features = (
    preprocessor.named_transformers_["ordinalencoder"].get_feature_names_out().tolist()
)
ohe_features = (
    preprocessor.named_transformers_["onehotencoder"].get_feature_names_out().tolist()
)

# Code to get all the feature names
feature_names = numeric_features + ordinal_enc_features + ohe_features

X_train_enc = pd.DataFrame(X_train_transformed, columns=feature_names)

# Show the transformed data
X_train_enc
```

Out[15]:

	LIMIT_BAL	AGE	BILL_AMT1	BILL_AMT2	BILL_AMT3	BILL_AMT4	BILL_AMT5	BILL_AMT6
0	0.251374	1.137475	0.940451	1.011211	1.104860	1.452507	1.629966	1.735910
1	-0.903088	-1.032623	-0.206290	-0.315498	-0.313130	-0.252458	-0.206105	-0.175015
2	0.328338	-0.598603	-0.596770	-0.566714	-0.521376	-0.592642	-0.567812	-0.494637
3	-0.595231	-0.924118	-0.062191	0.004463	0.020429	0.114755	0.204890	0.287074
4	-0.826124	0.486445	-0.438928	-0.408784	-0.370695	-0.321431	-0.264544	-0.218176
...	...	...	...	...	...	...	...	...
23995	-0.441303	-0.815613	-0.127294	-0.084612	-0.034217	0.036498	0.107612	0.155629
23996	-1.133980	0.269436	-0.529764	-0.532652	-0.560692	-0.615302	-0.604351	-0.562054
23997	-0.133447	0.703455	1.196416	1.294876	1.298797	1.474077	1.705212	1.640882
23998	0.174410	2.005514	2.102498	2.135467	2.158889	2.326124	1.988453	1.975903
23999	-0.518267	0.052426	-0.475904	-0.641158	-0.627059	-0.436640	-0.433289	-0.615381

24000 rows × 23 columns

In [16]:

```
import sys
from hashlib import sha1

import matplotlib.pyplot as plt
import numpy as np
import pandas as pd
from sklearn.dummy import DummyClassifier
from sklearn.feature_extraction.text import CountVectorizer
from sklearn.linear_model import LogisticRegression
from sklearn.model_selection import (
    GridSearchCV,
    RandomizedSearchCV,
    cross_validate,
    train_test_split,
)
from sklearn.neighbors import KNeighborsClassifier
from sklearn.naive_bayes import BernoulliNB, MultinomialNB
from sklearn.pipeline import Pipeline, make_pipeline
from sklearn.svm import SVC
from sklearn.tree import DecisionTreeClassifier
from sklearn.linear_model import RidgeClassifier
from sklearn.ensemble import RandomForestClassifier
```

In [17]:

```
models = {
    "dummy": DummyClassifier(random_state=123),
    "Decision Tree": DecisionTreeClassifier(random_state=123),
    "KNN": KNeighborsClassifier(),
    "RBF SVM": SVC(random_state=123),
    "Logistic Regression": LogisticRegression(max_iter=1000, random_state=123),
    "Ridge_cla": RidgeClassifier(random_state=123),
    "RandomForest_cla": RandomForestClassifier(random_state=123),
}

from sklearn.metrics import accuracy_score, f1_score, precision_score, recall_score

classification_metrics = ["accuracy", "precision", "recall", "f1"]

from collections import defaultdict
```

```python
cross_val_results = defaultdict(list)
for model in models:
    cross_val_results[model].append(
        cross_validate(
            make_pipeline(preprocessor, models[model]),
            X_train,
            y_train,
            cv=5,
            return_train_score=True,
            scoring=classification_metrics,
        )
    )
```

```
/opt/miniconda3/lib/python3.10/site-packages/sklearn/metrics/_classification.py:1334: Un
definedMetricWarning: Precision is ill-defined and being set to 0.0 due to no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
/opt/miniconda3/lib/python3.10/site-packages/sklearn/metrics/_classification.py:1334: Un
definedMetricWarning: Precision is ill-defined and being set to 0.0 due to no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
/opt/miniconda3/lib/python3.10/site-packages/sklearn/metrics/_classification.py:1334: Un
definedMetricWarning: Precision is ill-defined and being set to 0.0 due to no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
/opt/miniconda3/lib/python3.10/site-packages/sklearn/metrics/_classification.py:1334: Un
definedMetricWarning: Precision is ill-defined and being set to 0.0 due to no predicted
samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
/opt/miniconda3/lib/python3.10/site-packages/sklearn/model_selection/_validation.py:776:
UserWarning: Scoring failed. The score on this train-test partition for these parameters
will be set to nan. Details:
Traceback (most recent call last):
  File "/opt/miniconda3/lib/python3.10/site-packages/sklearn/metrics/_scorer.py", line 7
4, in _cached_call
    return cache[method]
KeyError: 'predict'

During handling of the above exception, another exception occurred:

Traceback (most recent call last):
  File "/opt/miniconda3/lib/python3.10/site-packages/sklearn/model_selection/_validatio
n.py", line 767, in _score
    scores = scorer(estimator, X_test, y_test)
  File "/opt/miniconda3/lib/python3.10/site-packages/sklearn/metrics/_scorer.py", line 1
06, in __call__
    score = scorer._score(cached_call, estimator, *args, **kwargs)
  File "/opt/miniconda3/lib/python3.10/site-packages/sklearn/metrics/_scorer.py", line 2
61, in _score
    y_pred = method_caller(estimator, "predict", X)
  File "/opt/miniconda3/lib/python3.10/site-packages/sklearn/metrics/_scorer.py", line 7
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r.py", line 763, in transform
    Xs = self._fit_transform(
  File "/opt/miniconda3/lib/python3.10/site-packages/sklearn/compose/_column_transforme
r.py", line 621, in _fit_transform
    return Parallel(n_jobs=self.n_jobs)(
  File "/opt/miniconda3/lib/python3.10/site-packages/joblib/parallel.py", line 1088, in
__call__
    while self.dispatch_one_batch(iterator):
  File "/opt/miniconda3/lib/python3.10/site-packages/joblib/parallel.py", line 901, in d
ispatch_one_batch
    self._dispatch(tasks)
  File "/opt/miniconda3/lib/python3.10/site-packages/joblib/parallel.py", line 819, in _
dispatch
    job = self._backend.apply_async(batch, callback=cb)
  File "/opt/miniconda3/lib/python3.10/site-packages/joblib/_parallel_backends.py", line
208, in apply_async
    result = ImmediateResult(func)
  File "/opt/miniconda3/lib/python3.10/site-packages/joblib/_parallel_backends.py", line
597, in __init__
    self.results = batch()
  File "/opt/miniconda3/lib/python3.10/site-packages/joblib/parallel.py", line 288, in _
_call__
    return [func(*args, **kwargs)
  File "/opt/miniconda3/lib/python3.10/site-packages/joblib/parallel.py", line 288, in <
listcomp>
    return [func(*args, **kwargs)
  File "/opt/miniconda3/lib/python3.10/site-packages/sklearn/utils/fixes.py", line 117,
in __call__
    return self.function(*args, **kwargs)
  File "/opt/miniconda3/lib/python3.10/site-packages/sklearn/pipeline.py", line 853, in
_transform_one
    res = transformer.transform(X)
  File "/opt/miniconda3/lib/python3.10/site-packages/sklearn/preprocessing/_encoders.p
y", line 1363, in transform
```

```
    X_int, X_mask = self._transform(
  File "/opt/miniconda3/lib/python3.10/site-packages/sklearn/preprocessing/_encoders.p
y", line 160, in _transform
    raise ValueError(msg)
ValueError: Found unknown categories [8] in column 5 during transform

  warnings.warn(
```

In [18]:

```
# code below modified from :https://stackoverflow.com/questions/13575090/
#               construct-pandas-dataframe-from-items-in-nested-dictionary
cross_val_results_df = (
    pd.concat(
        {
            key: pd.DataFrame(value[0]).agg(["mean", "std"])
            for key, value in cross_val_results.items()
        },
        axis=0,
    )
    .T.style.format(
        precision=2  # Pandas `.style` does not honor previous rounding via `.round()`
    )
    .background_gradient(
        axis=None,
        vmax=1,
        vmin=0,  # Color cells based on the entire matrix rather than row/column-wise
    )
)

cross_val_results_df
```

Out[18]:

	dummy		Decision Tree		KNN		RBF SVM		Logistic Regression		Ridge_cla		RandomForest
	mean	std	mean	std	mean	std	mean	std	mean	std	mean	std	mean
fit_time	0.02	0.00	0.36	0.07	0.02	0.00	5.23	0.12	0.10	0.01	0.02	0.00	3.25
score_time	0.01	0.00	0.01	0.01	0.09	0.08	0.84	0.76	0.01	0.00	0.01	0.00	0.04
test_accuracy	0.78	0.00	0.72	0.01	0.80	0.00	0.82	0.01	0.81	0.00	0.80	0.00	0.82
train_accuracy	0.78	0.00	1.00	0.00	0.84	0.00	0.82	0.00	0.81	0.00	0.80	0.00	1.00
test_precision	0.00	0.00	0.38	0.02	0.56	0.01	0.69	0.03	0.69	0.03	0.70	0.05	0.65
train_precision	0.00	0.00	1.00	0.00	0.73	0.01	0.71	0.01	0.70	0.01	0.71	0.01	1.00
test_recall	0.00	0.00	0.41	0.01	0.37	0.01	0.32	0.02	0.24	0.01	0.16	0.01	0.37
train_recall	0.00	0.00	1.00	0.00	0.47	0.00	0.33	0.01	0.25	0.01	0.16	0.01	1.00
test_f1	0.00	0.00	0.39	0.01	0.44	0.01	0.44	0.02	0.36	0.01	0.26	0.02	0.47
train_f1	0.00	0.00	1.00	0.00	0.57	0.00	0.45	0.01	0.37	0.01	0.26	0.01	1.00

In [ ]:

```
# Selecting RandomForestClassifier for model hyperparameter optimization.
from scipy.stats import loguniform
param_dist = {"ridge__alpha": loguniform(1e-3, 1e3)}
```