model

December 2, 2024

[1]:
```
import kagglehub
import pandas as pd
import matplotlib.pyplot as plt
import numpy as np

from sklearn.preprocessing import StandardScaler
from sklearn.model_selection import train_test_split, cross_val_score,␣
 ↪GridSearchCV
from sklearn.linear_model import LogisticRegression
from sklearn.neighbors import KNeighborsClassifier
from sklearn.metrics import confusion_matrix, classification_report,␣
 ↪ConfusionMatrixDisplay, roc_auc_score
from sklearn.ensemble import RandomForestClassifier

import torch
import torch.nn as nn
from torch.utils.data import DataLoader, TensorDataset

import xgboost as xgb

# Download the dataset
path = kagglehub.dataset_download("blastchar/telco-customer-churn")

print("Path to dataset files:", path)
```

```
/home/nicolas/miniconda3/envs/madkudu/lib/python3.11/site-
packages/tqdm/auto.py:21: TqdmWarning: IProgress not found. Please update
jupyter and ipywidgets. See
https://ipywidgets.readthedocs.io/en/stable/user_install.html
  from .autonotebook import tqdm as notebook_tqdm
```

```
Path to dataset files: /home/nicolas/.cache/kagglehub/datasets/blastchar/telco-
customer-churn/versions/1
```

0.1 1. Data Preprocessing

[2]:
```
import pandas as pd
df = pd.read_csv(path + "/WA_Fn-UseC_-Telco-Customer-Churn.csv")
df.head()
```

[2]:

	customerID	gender	SeniorCitizen	Partner	Dependents	tenure	PhoneService	…	DeviceProtection	TechSupport	StreamingTV	StreamingMovies	Contract	PaperlessBilling	PaymentMethod	MonthlyCharges	TotalCharges	Churn
0	7590-VHVEG	Female	0	Yes	No	1	No	…	No	No	No	No	Month-to-month	Yes	Electronic check	29.85	29.85	No
1	5575-GNVDE	Male	0	No	No	34	Yes	…	Yes	No	No	No	One year	No	Mailed check	56.95	1889.5	No
2	3668-QPYBK	Male	0	No	No	2	Yes	…	No	No	No	No	Month-to-month	Yes	Mailed check	53.85	108.15	Yes
3	7795-CFOCW	Male	0	No	No	45	No	…	Yes	Yes	No	No	One year	No	Bank transfer (automatic)	42.30	1840.75	No
4	9237-HQITU	Female	0	No	No	2	Yes	…	No	No	No	No	Month-to-month	Yes	Electronic check	70.70	151.65	Yes

[5 rows x 21 columns]

0.1.1 Data Exploration (Structure, Data types, Summary statistics)

[3]:
```
display(df.info())
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 7043 entries, 0 to 7042
Data columns (total 21 columns):
 #   Column            Non-Null Count  Dtype
---  ------            --------------  -----
 0   customerID        7043 non-null   object
 1   gender            7043 non-null   object
 2   SeniorCitizen     7043 non-null   int64
```

```
 3   Partner           7043 non-null   object
 4   Dependents        7043 non-null   object
 5   tenure            7043 non-null   int64
 6   PhoneService      7043 non-null   object
 7   MultipleLines     7043 non-null   object
 8   InternetService   7043 non-null   object
 9   OnlineSecurity    7043 non-null   object
 10  OnlineBackup      7043 non-null   object
 11  DeviceProtection  7043 non-null   object
 12  TechSupport       7043 non-null   object
 13  StreamingTV       7043 non-null   object
 14  StreamingMovies   7043 non-null   object
 15  Contract          7043 non-null   object
 16  PaperlessBilling  7043 non-null   object
 17  PaymentMethod     7043 non-null   object
 18  MonthlyCharges    7043 non-null   float64
 19  TotalCharges      7043 non-null   object
 20  Churn             7043 non-null   object
dtypes: float64(1), int64(2), object(18)
memory usage: 1.1+ MB
```

```
None
```

[4]:
```
df = df.drop(["customerID"], axis=1) # Dropping customerID as it is not useful␣
 ↪for the model

# Based on the dataset, columns with numerical values should be [tenure,␣
 ↪MonthlyCharges, TotalCharges]
numerical_cols = ["tenure", "MonthlyCharges", "TotalCharges"]
for col in numerical_cols:
    df[col] = pd.to_numeric(df[col], errors="coerce") # Converting columns to␣
 ↪numeric

display(df.head())
display(df[numerical_cols].describe())
```

```
   gender  SeniorCitizen Partner Dependents  tenure PhoneService  \
0  Female              0     Yes         No       1           No
1    Male              0      No         No      34          Yes
2    Male              0      No         No       2          Yes
3    Male              0      No         No      45           No
4  Female              0      No         No       2          Yes

      MultipleLines InternetService OnlineSecurity OnlineBackup  \
0  No phone service             DSL             No          Yes
1                No             DSL            Yes           No
2                No             DSL            Yes          Yes
3  No phone service             DSL            Yes           No
```

```
4                No     Fiber optic             No           No

  DeviceProtection TechSupport StreamingTV StreamingMovies        Contract  \
0               No          No          No              No  Month-to-month
1              Yes          No          No              No        One year
2               No          No          No              No  Month-to-month
3              Yes         Yes          No              No        One year
4               No          No          No              No  Month-to-month

  PaperlessBilling              PaymentMethod  MonthlyCharges  TotalCharges  \
0              Yes           Electronic check           29.85         29.85
1               No               Mailed check           56.95       1889.50
2              Yes               Mailed check           53.85        108.15
3               No  Bank transfer (automatic)           42.30       1840.75
4              Yes           Electronic check           70.70        151.65

  Churn
0    No
1    No
2   Yes
3    No
4   Yes
```

	tenure	MonthlyCharges	TotalCharges
count	7043.000000	7043.000000	7032.000000
mean	32.371149	64.761692	2283.300441
std	24.559481	30.090047	2266.771362
min	0.000000	18.250000	18.800000
25%	9.000000	35.500000	401.450000
50%	29.000000	70.350000	1397.475000
75%	55.000000	89.850000	3794.737500
max	72.000000	118.750000	8684.800000

0.1.2 Handling missing values

[5]:
```
print(df.isnull().sum())
```

```
gender              0
SeniorCitizen       0
Partner             0
Dependents          0
tenure              0
PhoneService        0
MultipleLines       0
InternetService     0
OnlineSecurity      0
OnlineBackup        0
DeviceProtection    0
```

```
TechSupport           0
StreamingTV           0
StreamingMovies       0
Contract              0
PaperlessBilling      0
PaymentMethod         0
MonthlyCharges        0
TotalCharges         11
Churn                 0
dtype: int64
```

[6]:
```
# There are 11 missing values in TotalCharges column. We can replace them with␣
 ↪the median value of the column.
df['TotalCharges'] = df['TotalCharges'].fillna(df['TotalCharges'].median())
```

0.1.3 Categorical Variables Encoding

[7]:
```
preprocessed_df = df.copy()

# Replacing categorical values with numerical values

preprocessed_df['gender'] = preprocessed_df['gender'].map({"Female": 0, "Male":␣
 ↪1})
binary_cols = ['Partner', 'Dependents', 'PhoneService', 'PaperlessBilling',␣
 ↪'Churn']
for col in binary_cols:
    preprocessed_df[col] = preprocessed_df[col].map({'Yes': 1, 'No': 0})

preprocessed_df = pd.get_dummies(preprocessed_df, columns=['MultipleLines',␣
 ↪'InternetService', 'OnlineSecurity', 'OnlineBackup', 'DeviceProtection',␣
 ↪'TechSupport', 'StreamingTV', 'StreamingMovies', 'Contract',␣
 ↪'PaymentMethod'], drop_first=True, dtype=int)
display(preprocessed_df.head())
```

```
   gender  SeniorCitizen  Partner  Dependents  tenure  PhoneService  \
0       0              0        1           0       1             0
1       1              0        0           0      34             1
2       1              0        0           0       2             1
3       1              0        0           0      45             0
4       0              0        0           0       2             1

   PaperlessBilling  MonthlyCharges  TotalCharges  Churn  …  \
0                 1           29.85         29.85      0  …
1                 0           56.95       1889.50      0  …
2                 1           53.85        108.15      1  …
3                 0           42.30       1840.75      0  …
4                 1           70.70        151.65      1  …
```

```
   TechSupport_Yes  StreamingTV_No internet service  StreamingTV_Yes  \
0                0                               0                0
1                0                               0                0
2                0                               0                0
3                1                               0                0
4                0                               0                0

   StreamingMovies_No internet service  StreamingMovies_Yes  \
0                                    0                    0
1                                    0                    0
2                                    0                    0
3                                    0                    0
4                                    0                    0

   Contract_One year  Contract_Two year  \
0                  0                  0
1                  1                  0
2                  0                  0
3                  1                  0
4                  0                  0

   PaymentMethod_Credit card (automatic)  PaymentMethod_Electronic check  \
0                                      0                               1
1                                      0                               0
2                                      0                               0
3                                      0                               0
4                                      0                               1

   PaymentMethod_Mailed check
0                           0
1                           1
2                           1
3                           0
4                           0

[5 rows x 31 columns]
```

[8]:
```
print(preprocessed_df.info())
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 7043 entries, 0 to 7042
Data columns (total 31 columns):
 #   Column                                 Non-Null Count  Dtype
---  ------                                 --------------  -----
 0   gender                                 7043 non-null   int64
 1   SeniorCitizen                          7043 non-null   int64
 2   Partner                                7043 non-null   int64
 3   Dependents                             7043 non-null   int64
```

```
 4   tenure                                   7043 non-null   int64
 5   PhoneService                             7043 non-null   int64
 6   PaperlessBilling                         7043 non-null   int64
 7   MonthlyCharges                           7043 non-null   float64
 8   TotalCharges                             7043 non-null   float64
 9   Churn                                    7043 non-null   int64
 10  MultipleLines_No phone service           7043 non-null   int64
 11  MultipleLines_Yes                        7043 non-null   int64
 12  InternetService_Fiber optic              7043 non-null   int64
 13  InternetService_No                       7043 non-null   int64
 14  OnlineSecurity_No internet service       7043 non-null   int64
 15  OnlineSecurity_Yes                       7043 non-null   int64
 16  OnlineBackup_No internet service         7043 non-null   int64
 17  OnlineBackup_Yes                         7043 non-null   int64
 18  DeviceProtection_No internet service     7043 non-null   int64
 19  DeviceProtection_Yes                     7043 non-null   int64
 20  TechSupport_No internet service          7043 non-null   int64
 21  TechSupport_Yes                          7043 non-null   int64
 22  StreamingTV_No internet service          7043 non-null   int64
 23  StreamingTV_Yes                          7043 non-null   int64
 24  StreamingMovies_No internet service      7043 non-null   int64
 25  StreamingMovies_Yes                      7043 non-null   int64
 26  Contract_One year                        7043 non-null   int64
 27  Contract_Two year                        7043 non-null   int64
 28  PaymentMethod_Credit card (automatic)    7043 non-null   int64
 29  PaymentMethod_Electronic check           7043 non-null   int64
 30  PaymentMethod_Mailed check               7043 non-null   int64
dtypes: float64(2), int64(29)
memory usage: 1.7 MB
None
```

0.1.4 Scaling Numerical Values

[21]:
```
# Scaling the numerical columns
scaler = StandardScaler()
scaled_df = preprocessed_df.copy()

for col in numerical_cols:
    scaled_df[col] = scaler.fit_transform(scaled_df[[col]])

final_df = scaled_df.copy()
final_df.to_csv("preprocessed_data.csv", index=False)
final_df.head()
```

[21]:

	gender	SeniorCitizen	Partner	Dependents	tenure	PhoneService	\
0	0	0	1	0	-1.277445	0	
1	1	0	0	0	0.066327	1	

```
2       1              0        0           0 -1.236724             1
3       1              0        0           0  0.514251             0
4       0              0        0           0 -1.236724             1

   PaperlessBilling  MonthlyCharges  TotalCharges  Churn  … \
0                 1       -1.160323     -0.994242      0  …
1                 0       -0.259629     -0.173244      0  …
2                 1       -0.362660     -0.959674      1  …
3                 0       -0.746535     -0.194766      0  …
4                 1        0.197365     -0.940470      1  …

   TechSupport_Yes  StreamingTV_No internet service  StreamingTV_Yes  \
0                0                                0                0
1                0                                0                0
2                0                                0                0
3                1                                0                0
4                0                                0                0

   StreamingMovies_No internet service  StreamingMovies_Yes  \
0                                    0                    0
1                                    0                    0
2                                    0                    0
3                                    0                    0
4                                    0                    0

   Contract_One year  Contract_Two year  \
0                  0                  0
1                  1                  0
2                  0                  0
3                  1                  0
4                  0                  0

   PaymentMethod_Credit card (automatic)  PaymentMethod_Electronic check  \
0                                      0                               1
1                                      0                               0
2                                      0                               0
3                                      0                               0
4                                      0                               1

   PaymentMethod_Mailed check
0                           0
1                           1
2                           1
3                           0
4                           0

[5 rows x 31 columns]
```

0.2 2. Model devlopment

[22]:
```
X = final_df.drop('Churn', axis=1)
y = final_df['Churn']

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

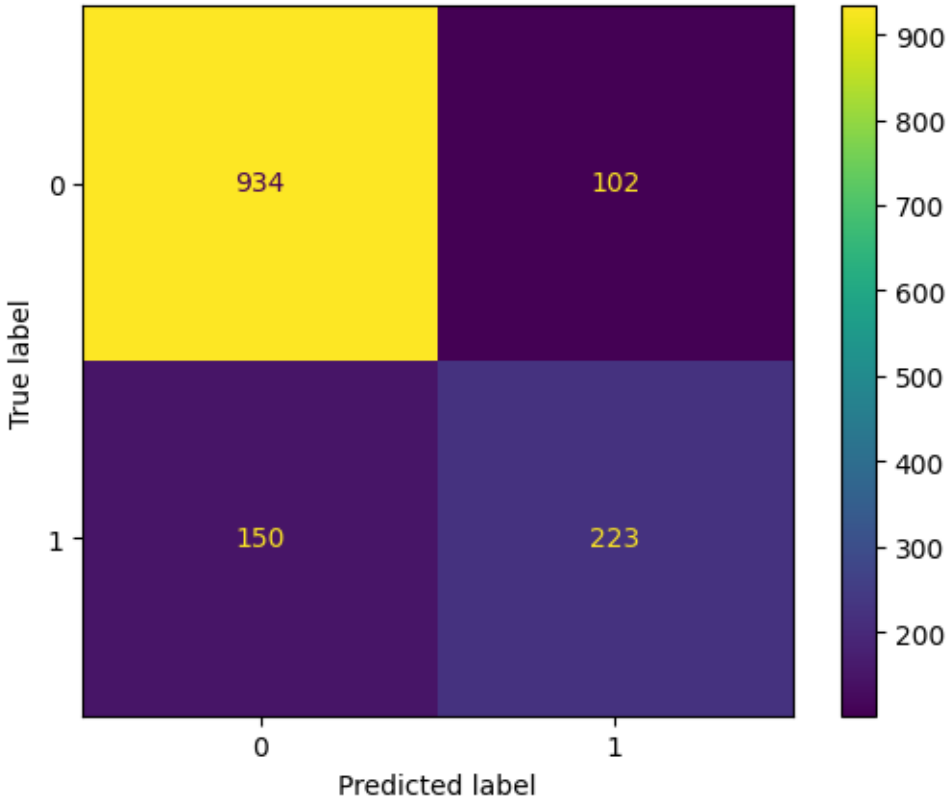
[11]:
```
def train_and_evaluate_model(X_train, X_test, y_train, y_test, model):
    model.fit(X_train, y_train)
    y_pred = model.predict(X_test)

    cm = confusion_matrix(y_test, y_pred, labels=model.classes_)
    disp = ConfusionMatrixDisplay(confusion_matrix=cm, display_labels=model.
↪classes_)
    disp.plot()

    print("\nClassification Report:")
    print(classification_report(y_test, y_pred))

    return model
```

0.2.1 Logistic Regression

[12]:
```
model = LogisticRegression()
model = train_and_evaluate_model(X_train, X_test, y_train, y_test, model)

y_pred = model.predict(X_test)

# Cross validation
scores = cross_val_score(model, X, y, cv=5)
print("Cross validation scores:", scores)
print("Mean cross validation score:", scores.mean())

# Using AUC-ROC score
roc_auc = roc_auc_score(y_test, y_pred)
print("AUC-ROC score:", roc_auc)
```

```
Classification Report:
              precision    recall  f1-score   support

           0       0.86      0.90      0.88      1036
           1       0.69      0.60      0.64       373

    accuracy                           0.82      1409
   macro avg       0.77      0.75      0.76      1409
weighted avg       0.82      0.82      0.82      1409
```

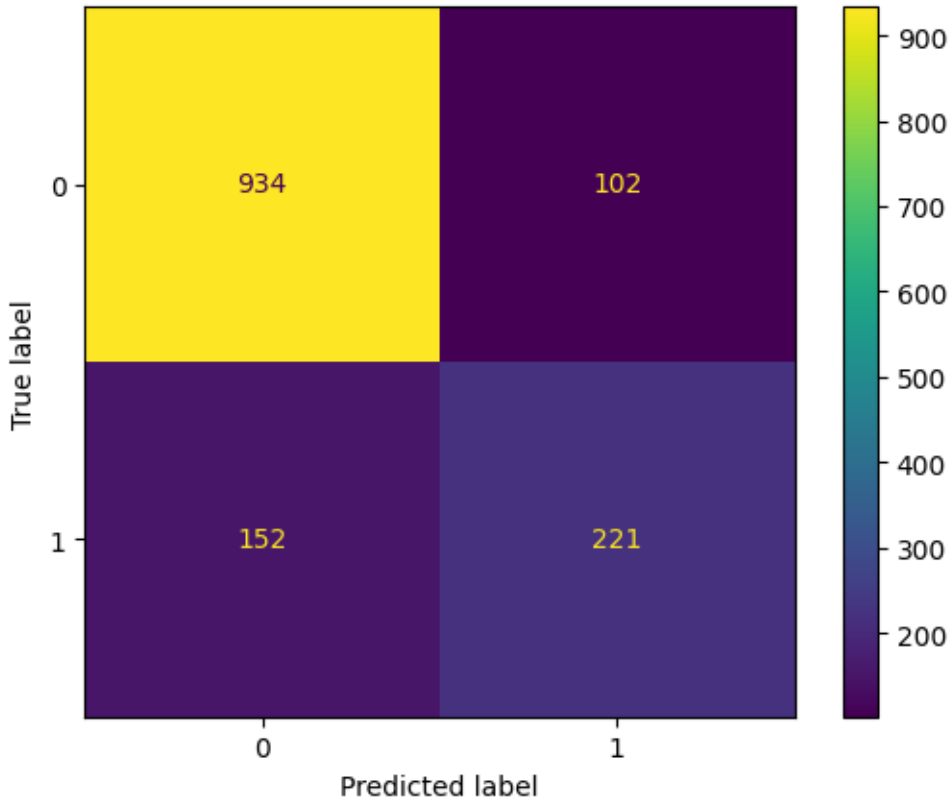
```
Cross validation scores: [0.80411639 0.81121363 0.79063165 0.81107955
0.80397727]
Mean cross validation score: 0.8042036986257177
AUC-ROC score: 0.7496998147132194
```



[13]:
```
param_grid = {
    'C': [0.01, 0.1, 1, 10, 100],
    'penalty': ['l2'],
    'solver': ['lbfgs', 'liblinear']
}

grid_search = GridSearchCV(LogisticRegression(), param_grid, cv=5)
grid_search.fit(X_train, y_train)

print("Best parameters:", grid_search.best_params_)
print("Best cross-validation score:", grid_search.best_score_)
print("Test set score:", grid_search.score(X_test, y_test))
print("AUC-ROC score", roc_auc_score(y_test, grid_search.predict(X_test)))

model = LogisticRegression(**grid_search.best_params_)
```

```
model = train_and_evaluate_model(X_train, X_test, y_train, y_test, model)
```

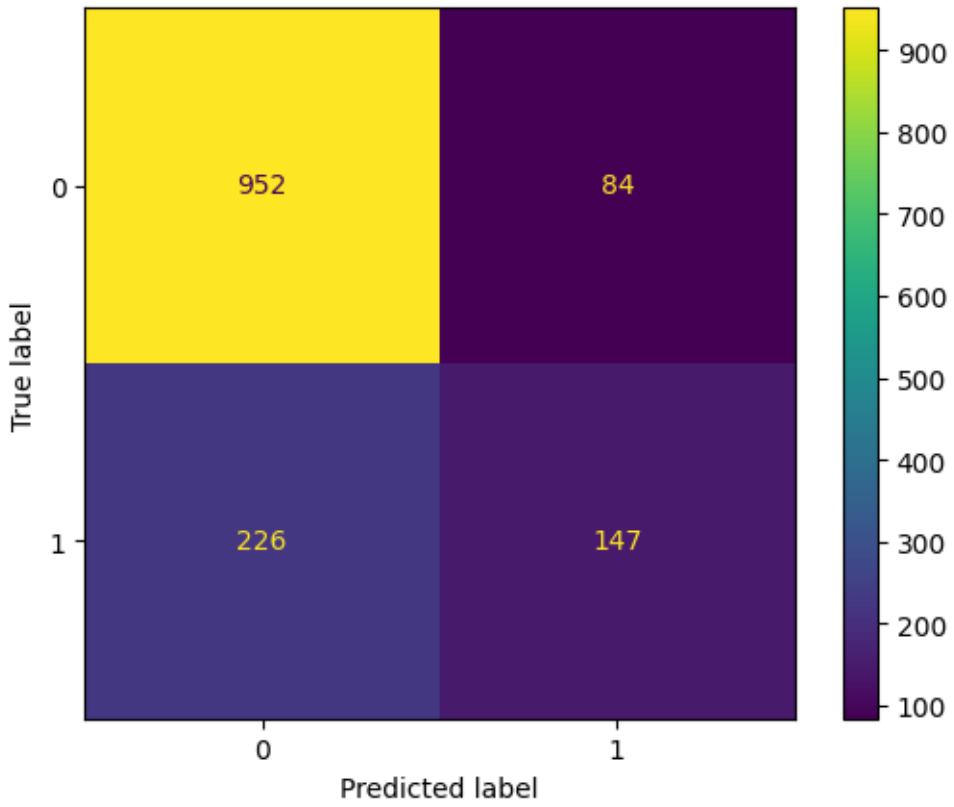
```
Best parameters: {'C': 100, 'penalty': 'l2', 'solver': 'liblinear'}
Best cross-validation score: 0.8020950321591297
Test set score: 0.8197303051809794
AUC-ROC score 0.7470188495657665

Classification Report:
              precision    recall  f1-score   support

           0       0.86      0.90      0.88      1036
           1       0.68      0.59      0.64       373

    accuracy                           0.82      1409
   macro avg       0.77      0.75      0.76      1409
weighted avg       0.81      0.82      0.82      1409
```



0.2.2 KNeighbors

[14]:
```
model = KNeighborsClassifier(n_neighbors=4)
model = train_and_evaluate_model(X_train, X_test, y_train, y_test, model)
```

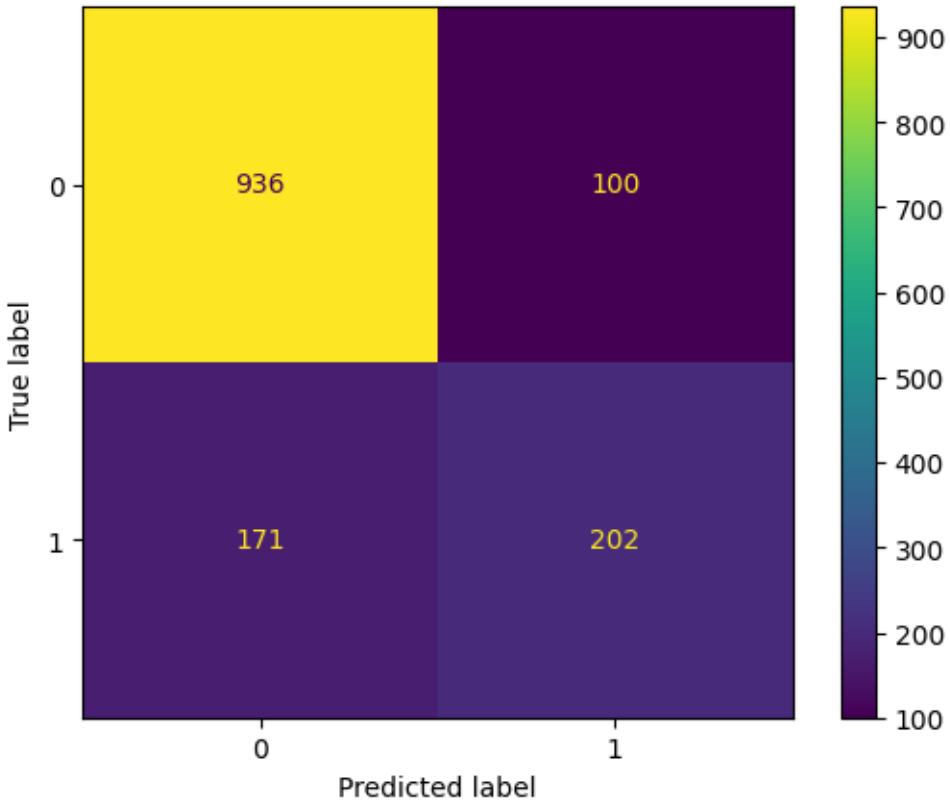
```
Classification Report:
              precision    recall  f1-score   support

           0       0.81      0.92      0.86      1036
           1       0.64      0.39      0.49       373

    accuracy                           0.78      1409
   macro avg       0.72      0.66      0.67      1409
weighted avg       0.76      0.78      0.76      1409
```



[15]:
```
# Grid search for hyperparameter tuning

param_grid = {
    'n_neighbors': np.arange(1, 20),
    'weights': ['uniform', 'distance'],
```

```
    'metric': ['euclidean', 'manhattan']
}

grid_search = GridSearchCV(KNeighborsClassifier(), param_grid, cv=5)
grid_search.fit(X_train, y_train)

print("Best parameters:", grid_search.best_params_)
print("Best cross-validation score:", grid_search.best_score_)
print("Test set score:", grid_search.score(X_test, y_test))
print("AUC-ROC score", roc_auc_score(y_test, grid_search.predict(X_test)))


model = KNeighborsClassifier(n_neighbors=grid_search.
 ↪best_params_['n_neighbors'], weights=grid_search.best_params_['weights'],␣
 ↪metric=grid_search.best_params_['metric'])
model = train_and_evaluate_model(X_train, X_test, y_train, y_test, model)
```

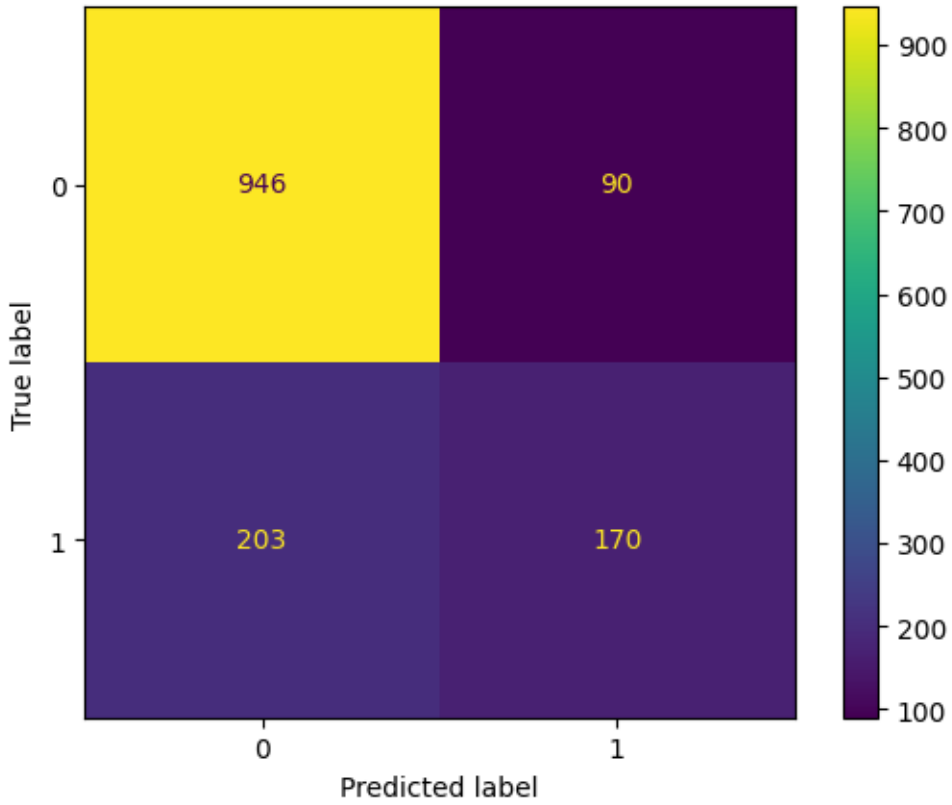
```
Best parameters: {'metric': 'manhattan', 'n_neighbors': np.int64(18), 'weights':
'uniform'}
Best cross-validation score: 0.7926889004115045
Test set score: 0.8076650106458482
AUC-ROC score 0.7225149316302131

Classification Report:
              precision    recall  f1-score   support

           0       0.85      0.90      0.87      1036
           1       0.67      0.54      0.60       373

    accuracy                           0.81      1409
   macro avg       0.76      0.72      0.74      1409
weighted avg       0.80      0.81      0.80      1409
```



0.2.3 Random Forest

[16]:
```
model = RandomForestClassifier(n_estimators=100, random_state=42)
model = train_and_evaluate_model(X_train, X_test, y_train, y_test, model)
```

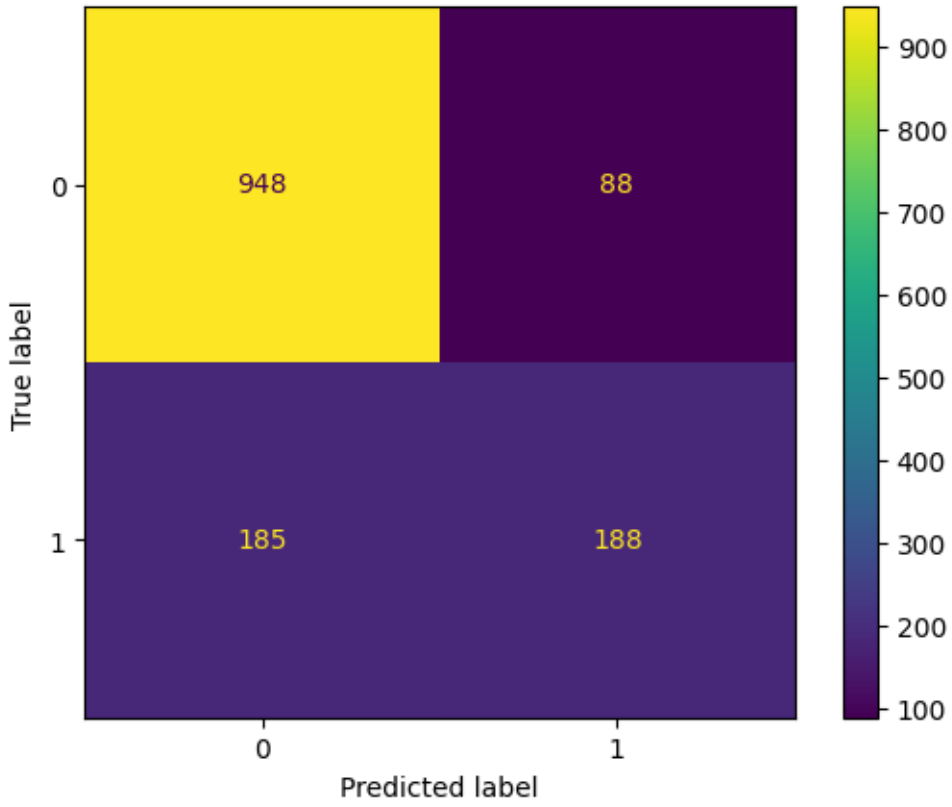
```
Classification Report:
              precision    recall  f1-score   support

           0       0.82      0.91      0.87      1036
           1       0.65      0.46      0.54       373

    accuracy                           0.79      1409
   macro avg       0.74      0.68      0.70      1409
weighted avg       0.78      0.79      0.78      1409
```



[17]:
```
param_grid = {
    'n_estimators': [100, 200, 300],
    'max_depth': [10, 20, 30, 40, 50],
    'min_samples_split': [2, 5, 10],
    'min_samples_leaf': [1, 2, 4]
}

grid_search = GridSearchCV(RandomForestClassifier(), param_grid, cv=5)
grid_search.fit(X_train, y_train)

print("Best parameters:", grid_search.best_params_)
print("Best cross-validation score:", grid_search.best_score_)
print("Test set score:", grid_search.score(X_test, y_test))
print("AUC-ROC score", roc_auc_score(y_test, grid_search.predict(X_test)))

model = RandomForestClassifier(**grid_search.best_params_)
model = train_and_evaluate_model(X_train, X_test, y_train, y_test, model)
```

```
/home/nicolas/miniconda3/envs/madkudu/lib/python3.11/site-
packages/numpy/ma/core.py:2881: RuntimeWarning: invalid value encountered in
cast
```

```
  _data = np.array(data, dtype=dtype, copy=copy,
Best parameters: {'max_depth': 30, 'min_samples_leaf': 4, 'min_samples_split':
5, 'n_estimators': 200}
Best cross-validation score: 0.8052882501367215
Test set score: 0.8097941802696949
AUC-ROC score 0.7136685229848768

Classification Report:
              precision    recall  f1-score   support

           0       0.84      0.92      0.87      1036
           1       0.68      0.50      0.58       373

    accuracy                           0.81      1409
   macro avg       0.76      0.71      0.73      1409
weighted avg       0.80      0.81      0.80      1409
```



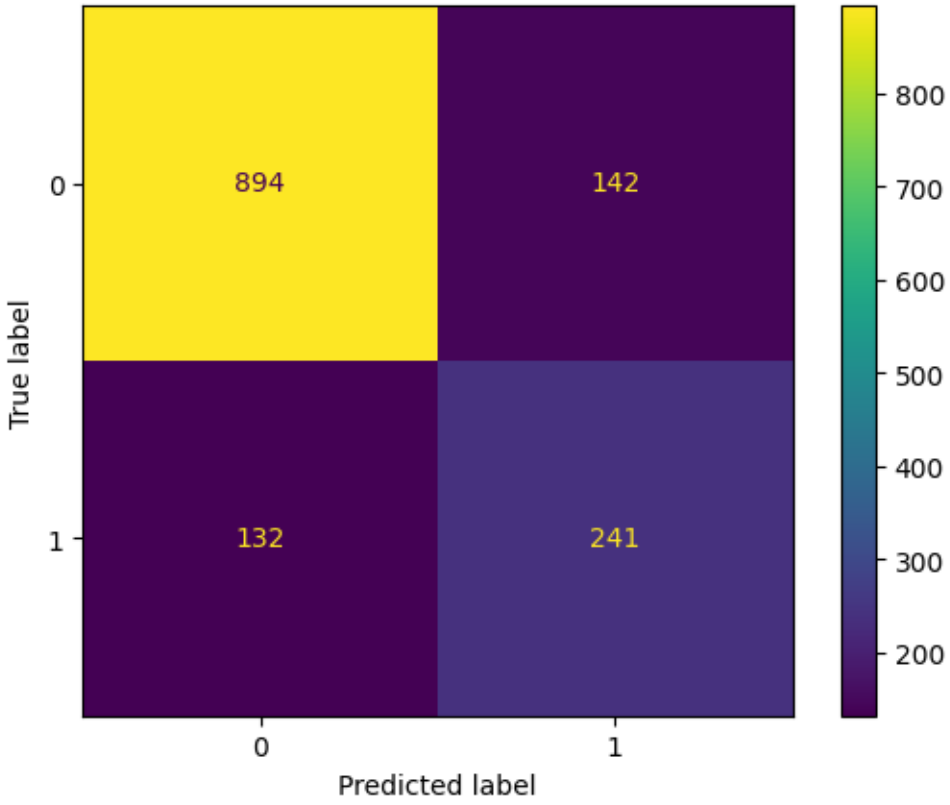
0.2.4 Neural Network

[18]:
```
class NeuralNetwork(nn.Module):
    def __init__(self, input_dim, hidden_dim, output_dim):
        super(NeuralNetwork, self).__init__()
        self.fc1 = nn.Linear(input_dim, hidden_dim)
        self.fc2 = nn.Linear(hidden_dim, output_dim)
        self.relu = nn.ReLU()
        self.sigmoid = nn.Sigmoid()

    def forward(self, x):
        x = self.relu(self.fc1(x))
        x = self.sigmoid(self.fc2(x))
        return x

X_train_tensor = torch.tensor(X_train.values, dtype=torch.float32)
y_train_tensor = torch.tensor(y_train.values, dtype=torch.float32).view(-1, 1)
X_test_tensor = torch.tensor(X_test.values, dtype=torch.float32)
y_test_tensor = torch.tensor(y_test.values, dtype=torch.float32).view(-1, 1)

batch_size = 64
train_dataset = TensorDataset(X_train_tensor, y_train_tensor)
train_loader = DataLoader(train_dataset, batch_size=batch_size, shuffle=True)

input_dim = X_train.shape[1]
hidden_dim = 32
output_dim = 1

model = NeuralNetwork(input_dim, hidden_dim, output_dim)
pos_weight = torch.tensor([len(y_train[y_train == 0]) / len(y_train[y_train ==␣
 ↪1])], dtype=torch.float32)
criterion = nn.BCEWithLogitsLoss(pos_weight=pos_weight)
optimizer = torch.optim.Adam(model.parameters(), lr=0.01)

best_loss = float('inf')
patience = 10
patience_counter = 0

for epoch in range(1000):
    model.train()
    epoch_loss = 0

    for X_batch, y_batch in train_loader:
        optimizer.zero_grad()
        outputs = model(X_batch)
        loss = criterion(outputs, y_batch)
        loss.backward()
```

```
        optimizer.step()
        epoch_loss += loss.item()

    epoch_loss /= len(train_loader)

    if epoch % 10 == 0:
        print(f"Epoch {epoch}, Loss: {epoch_loss}")

    if epoch_loss < best_loss:
        best_loss = epoch_loss
        patience_counter = 0
    else:
        patience_counter += 1
        if patience_counter >= patience:
            print("Early stopping triggered")
            break

model.eval()
with torch.no_grad():
    y_pred_prob = model(X_test_tensor).numpy()
    y_pred = (y_pred_prob > 0.5).astype(int)

cm = confusion_matrix(y_test, y_pred, labels=[0, 1])
disp = ConfusionMatrixDisplay(confusion_matrix=cm, display_labels=[0, 1])
disp.plot()

print("\nClassification Report:")
print(classification_report(y_test, y_pred))

roc_auc = roc_auc_score(y_test, y_pred_prob)
print("AUC-ROC score:", roc_auc)
```

```
Epoch 0, Loss: 0.9348100618030248
Epoch 10, Loss: 0.9085054672166203
Epoch 20, Loss: 0.8999583881892516
Epoch 30, Loss: 0.8933689192439733
Epoch 40, Loss: 0.8895155399033193
Epoch 50, Loss: 0.8836978935123829
Epoch 60, Loss: 0.8811845143189591
Epoch 70, Loss: 0.8788104646661309
Early stopping triggered

Classification Report:
              precision    recall  f1-score   support

           0       0.87      0.86      0.87      1036
           1       0.63      0.65      0.64       373
```

```
    accuracy                           0.81      1409
   macro avg       0.75      0.75      0.75      1409
weighted avg       0.81      0.81      0.81      1409

AUC-ROC score: 0.8506888734770773
```



0.2.5 XGBoost

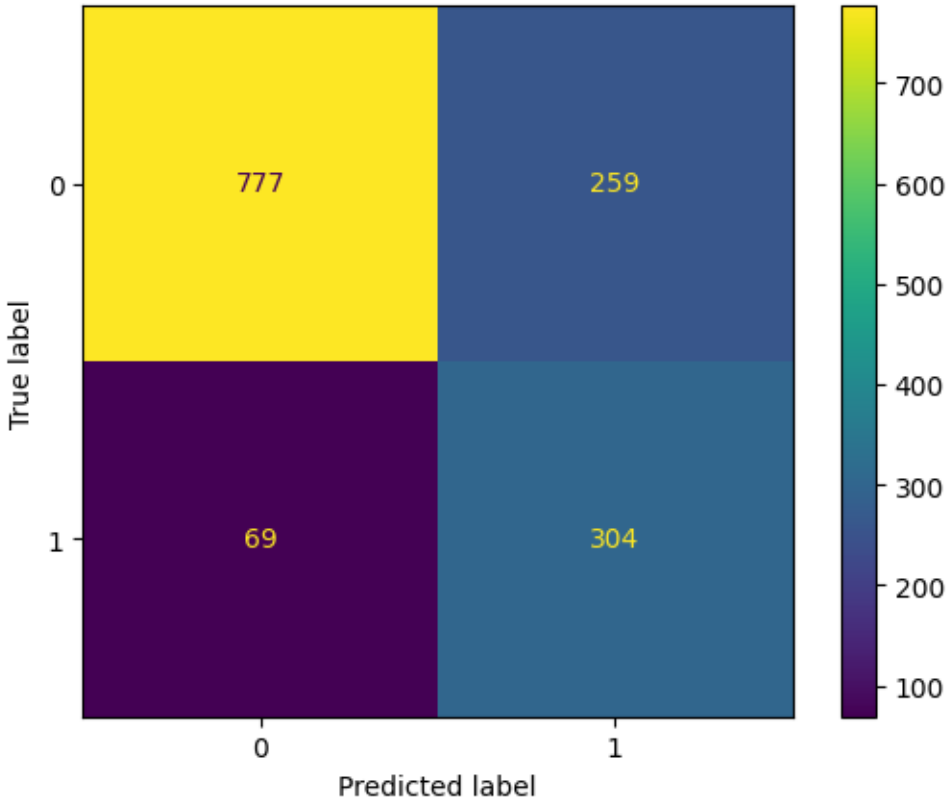
[19]:
```
negative_class = len(y_train[y_train == 0])
positive_class = len(y_train[y_train == 1])
scale_pos_weight = negative_class / positive_class

dtrain = xgb.DMatrix(X_train, label=y_train)
dtest = xgb.DMatrix(X_test, label=y_test)

params = {
    'objective': 'binary:logistic',
    'scale_pos_weight': scale_pos_weight,
    'eval_metric': 'auc',
    'max_depth': 6,          # Depth of the trees
    'learning_rate': 0.1,    # Step size shrinkage
```

```
    'n_estimators': 100,    # Number of boosting rounds
    'subsample': 0.8,       # Randomly sample training data
    'colsample_bytree': 0.8 # Randomly sample features for each tree
}

model = xgb.train(
    params,
    dtrain,
    num_boost_round=200,
    evals=[(dtrain, 'train'), (dtest, 'test')],
    early_stopping_rounds=10,
    verbose_eval=10
)


y_pred_prob = model.predict(dtest)
y_pred = (y_pred_prob > 0.5).astype(int)

# Confusion Matrix
cm = confusion_matrix(y_test, y_pred)
disp = ConfusionMatrixDisplay(confusion_matrix=cm, display_labels=[0, 1])
disp.plot()

# Classification Report
print("\nClassification Report:")
print(classification_report(y_test, y_pred))

# AUC-ROC Score
roc_auc = roc_auc_score(y_test, y_pred_prob)
print("AUC-ROC score:", roc_auc)
```

```
[0]     train-auc:0.85001       test-auc:0.83997
[10]    train-auc:0.87805       test-auc:0.85796
[20]    train-auc:0.88602       test-auc:0.85903
[30]    train-auc:0.89448       test-auc:0.85833
[31]    train-auc:0.89576       test-auc:0.85841
```

```
/home/nicolas/miniconda3/envs/madkudu/lib/python3.11/site-
packages/xgboost/core.py:158: UserWarning: [02:20:16] WARNING:
/workspace/src/learner.cc:740:
Parameters: { "n_estimators" } are not used.

  warnings.warn(smsg, UserWarning)


Classification Report:
              precision    recall  f1-score   support

           0       0.92      0.75      0.83      1036
```

```
              1       0.54      0.82      0.65       373

    accuracy                           0.77      1409
   macro avg       0.73      0.78      0.74      1409
weighted avg       0.82      0.77      0.78      1409

AUC-ROC score: 0.858020122765431
```



[24]:
```python
model.save_model('xgboost_model.json')

# Save data with predictions
data = pd.read_csv("preprocessed_data.csv")

def predict_churn(row):
    data = pd.DataFrame([row])
    dtest = xgb.DMatrix(data.drop(['Churn'], axis=1))

    churn_probability = model.predict(dtest)[0]
    churn_label = "Churn" if churn_probability > 0.5 else "No Churn"

    return churn_probability, churn_label
```

```
data['ChurnProbability'], data['ChurnPrediction'] = zip(*data.
 ↪apply(predict_churn, axis=1))
data.to_csv("churn_predictions.csv", index=False)
```

[ ]: