

04 — Modelling v2 (ML)

This notebook builds and explores ML models which predict the propensity of patients to be readmitted, but this time incorporating features derived from the ICD-9 diagnostic codes.

Local data source: /data/interim/10kDiabetes.csv

Executive Summary

This notebook evaluates whether enriching the feature set with ICD-9 diagnostic codes improves model performance over the baseline model in 02_Model.

As seen in [01_EDA.ipynb], raw ICD-9 codes greatly expand the feature space, creating a high-dimensional and sparse matrix that is difficult for classical models to learn from without substantial work (feature engineering).

Initial experiments show that simply one-hot encoding diagnosis codes does **not** yield meaningful performance improvements. Extracting value from ICD-9 data will very likely require grouping codes into identifiable comorbidities, which was outside scope given the time constraints.

This notebook therefore demonstrates that throwing extra features and compute at the problem (ICD-9 feature expansion) does not provide a “**quick win**”.

The **Logistic Regression** baseline model remains the best predictive model available at this point, benefitting additionally from reliability and explainability (**xAI; SHAP**).

Model	ROC-AUC	PR-AUC	Notes
Logistic Regression	0.703	0.600	Best overall, stable
Random Forest	0.685	0.556	Oversampling observed
LR + ICD-9 features	~0.69	~0.58	No improvement

1. Imports and Project Setup

```
In [1]: import sys
import os

project_root = os.path.abspath("..") # Add project root to Python path so we can import data_loader, preprocess, etc etc
if project_root not in sys.path:
    sys.path.append(project_root)

project_root
```

```
Out[1]: 'C:\\\\work\\\\git\\\\diabetes-readmission-ml'
```

```
In [2]: import warnings
with warnings.catch_warnings():
    warnings.filterwarnings("ignore") # Not too bothered about message "Pyarrow will become a required dependency of pandas"
    import pandas as pd

import numpy as np
import missingno as msno

import matplotlib.pyplot as plt
import seaborn as sns
sns.set_theme(style="whitegrid", font_scale=1.4) # try 1.3-1.6

from src.data_loader import load_diabetes_csv, DIABETES_DATA_CSV

plt.style.use("seaborn-v0_8")
pd.set_option("display.max_columns", None)
```

```
In [3]: df = load_diabetes_csv(DIABETES_DATA_CSV, project_root)
df.shape
```

```
Out[3]: (10000, 52)
```

```
In [4]: from src.extract_diag import preprocess_extract_diag
df = preprocess_extract_diag(df, 'readmitted')
```

```
In [5]: df[['diag_1_norm', 'diag_1_norm', 'diag_1_norm', 'has_V', 'has_E', 'diag_count', 'readmitted']].head(20)
```

	diag_1_norm	diag_1_norm	diag_1_norm	has_V	has_E	diag_count	readmitted
0	723	723	723	0	0	2	False
1	664	664	664	0	0	3	False
2	481	481	481	0	0	3	True
3	682	682	682	0	0	3	False
4	296	296	296	0	0	3	False
5	428	428	428	0	0	3	False
6	434	434	434	0	0	3	False
7	558	558	558	0	0	3	False
8	428	428	428	0	0	3	False
9	440	440	440	0	0	2	True
10	997	997	997	0	0	3	False
11	250	250	250	0	0	3	False
12	250	250	250	0	0	3	False
13	428	428	428	0	0	3	True
14	584	584	584	0	0	3	False
15	414	414	414	0	0	3	False
16	250	250	250	0	0	3	False
17	415	415	415	0	0	3	True
18	432	432	432	1	0	3	True
19	786	786	786	0	0	3	True

```
In [6]: from src.preprocess import preprocess_impute_scale_encode

ignorelist = ['diag_1', 'diag_2', 'diag_3', 'max_glu_serum', 'A1CResult', 'diag_1_desc', 'diag_2_desc', 'diag_3_desc']
df = df.drop(columns=ignorelist, errors='ignore')

df_preproc = preprocess_impute_scale_encode(df, 'readmitted')
```

Models

```
In [9]: # 2.2 Train/Test Split & Baseline Models

from sklearn.model_selection import train_test_split
from sklearn.linear_model import LogisticRegression
from sklearn.ensemble import RandomForestClassifier
from sklearn.metrics import (
    accuracy_score, precision_score, recall_score,
    f1_score, roc_auc_score, precision_recall_curve
)

# Assume df_processed is your cleaned DataFrame & 'readmitted' is target
X = df_preproc.drop(columns=['readmitted'])
y = df_preproc['readmitted']

X_train, X_test, y_train, y_test = train_test_split(
    X, y, test_size=0.2, stratify=y, random_state=42
)

# Baseline models
models = {
    'LogisticRegression': LogisticRegression(max_iter=1000, random_state=42),
    'RandomForest': RandomForestClassifier(n_estimators=100, random_state=42)
}

results = {}

y_pred = dict()
y_proba = dict()

for name, model in models.items():
    model.fit(X_train, y_train)
    y_pred[name] = model.predict(X_test)
    y_proba[name] = model.predict_proba(X_test)[:, 1]

    results[name] = {
        'Accuracy': accuracy_score(y_test, y_pred[name]),
        'Precision': precision_score(y_test, y_pred[name]),
        'Recall': recall_score(y_test, y_pred[name]),
        'F1': f1_score(y_test, y_pred[name]),
        'ROC-AUC': roc_auc_score(y_test, y_proba[name])
    }

import pandas as pd
results_df = pd.DataFrame(results).T
results_df
```

	Accuracy	Precision	Recall	F1	ROC-AUC
LogisticRegression	0.6605	0.594684	0.451450	0.513262	0.683292
RandomForest	0.6585	0.631579	0.332913	0.436003	0.685677

Logistic Regression

```
In [12]: from sklearn.model_selection import learning_curve
import numpy as np
import matplotlib.pyplot as plt

train_sizes, train_scores, val_scores = learning_curve(
```

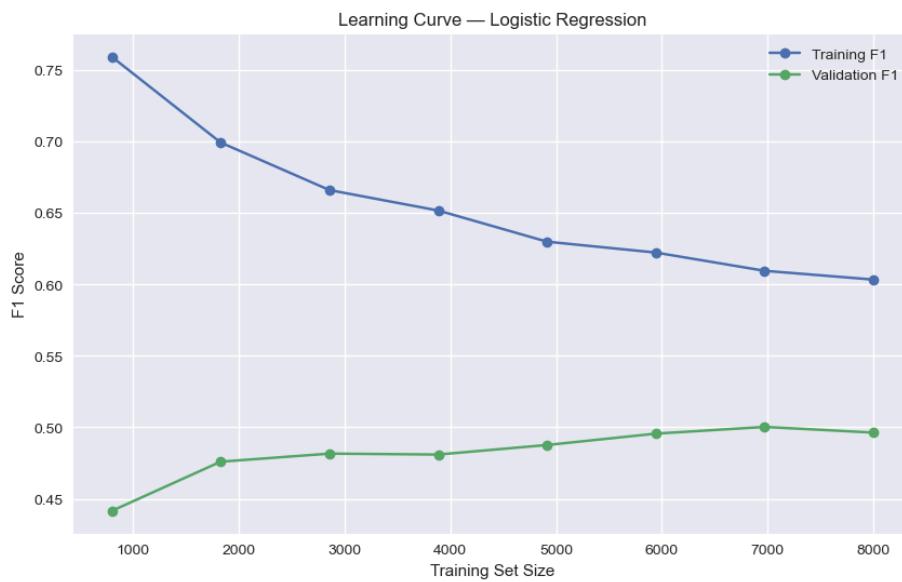
```

        models['LogisticRegression'],
        X, y,
        train_sizes=np.linspace(0.1, 1.0, 8),
        cv=5,
        scoring='f1',
        n_jobs=-1
    )

train_mean = train_scores.mean(axis=1)
val_mean = val_scores.mean(axis=1)

plt.figure(figsize=(10, 6))
plt.plot(train_sizes, train_mean, 'o-', label='Training F1')
plt.plot(train_sizes, val_mean, 'o-', label='Validation F1')
plt.xlabel('Training Set Size')
plt.ylabel('F1 Score')
plt.title('Learning Curve — Logistic Regression')
plt.grid(True)
plt.legend()
plt.show()

```

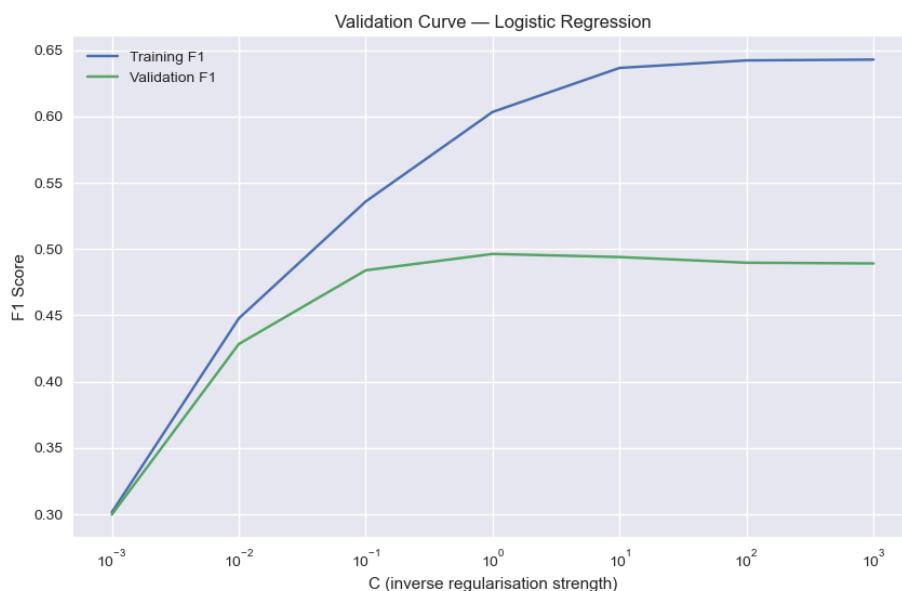


```
In [13]: from sklearn.model_selection import validation_curve

param_range = np.logspace(-3, 3, 7)

train_scores, val_scores = validation_curve(
    models['LogisticRegression'],
    X, y,
    param_name='C',
    param_range=param_range,
    cv=5,
    scoring='f1',
    n_jobs=-1
)

plt.figure(figsize=(10, 6))
plt.semilogx(param_range, train_scores.mean(axis=1), label="Training F1")
plt.semilogx(param_range, val_scores.mean(axis=1), label="Validation F1")
plt.xlabel('C (inverse regularisation strength)')
plt.ylabel('F1 Score')
plt.title('Validation Curve — Logistic Regression')
plt.grid(True)
plt.legend()
plt.show()
```



```
In [14]: from sklearn.metrics import precision_recall_curve, auc, average_precision_score
import matplotlib.pyplot as plt

model_choice = 'LogisticRegression'
# Assume:
#   y_test - the actual binary Labels (0/1) for the test set
#   y_proba - the predicted probabilities for the positive class (model.predict_proba(X_test)[:,1])

# Compute precision/recall pairs for various thresholds
precision, recall, thresholds = precision_recall_curve(y_test, y_proba[model_choice])

# Compute average precision (PR-AUC)
pr_auc = average_precision_score(y_test, y_proba[model_choice])

# Compute area under the precision-recall curve (alternate)
pr_auc_trap = auc(recall, precision)

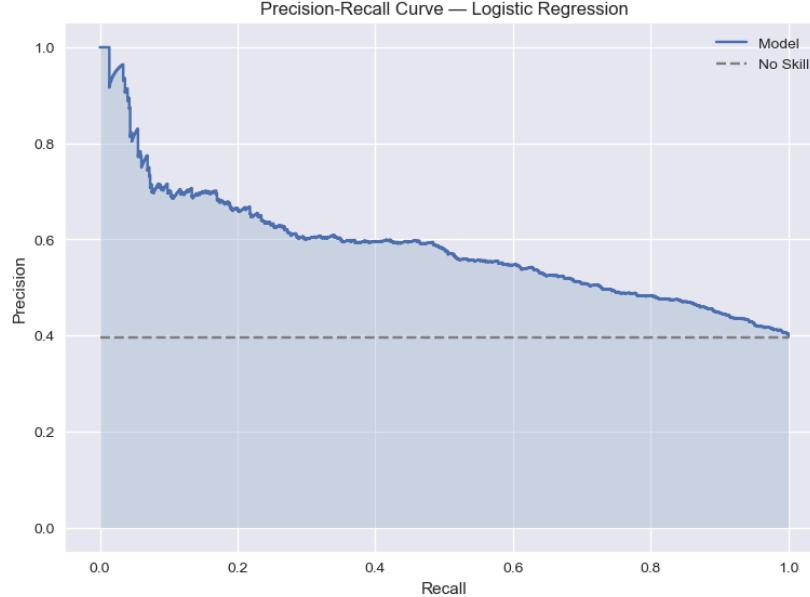
print(f"Average Precision (PR-AUC): {pr_auc:.3f}")
print(f"Area under PR-curve (by trapezoid): {pr_auc_trap:.3f}")

# Plot the precision-recall curve
plt.figure(figsize=(8, 6))
plt.step(recall, precision, where='post', label='Model')
plt.fill_between(recall, precision, step='post', alpha=0.2)

# Plot the no-skill line (precision equal to prevalence)
no_skill = sum(y_test==1) / len(y_test)
plt.hlines(no_skill, 0, 1, linestyle='--', color='grey', label='No Skill')

plt.xlabel('Recall')
plt.ylabel('Precision')
plt.title('Precision-Recall Curve - Logistic Regression')
plt.legend()
plt.grid(True)
plt.tight_layout()
plt.show()
```

Average Precision (PR-AUC): 0.583
 Area under PR-curve (by trapezoid): 0.583



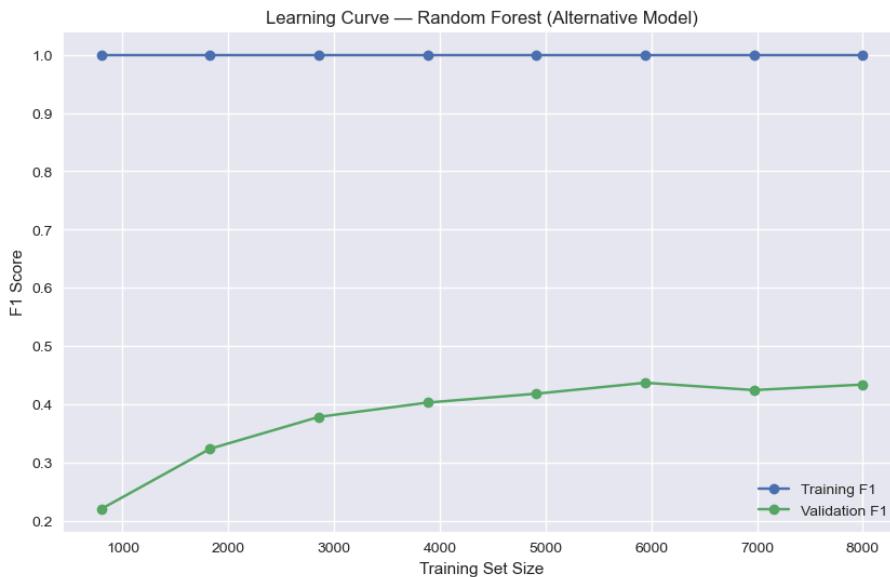
Random Forest

```
In [15]: from sklearn.model_selection import learning_curve
import numpy as np
import matplotlib.pyplot as plt

train_sizes, train_scores, val_scores = learning_curve(
    models['RandomForest'],
    X,
    y,
    train_sizes=np.linspace(0.1, 1.0, 8),
    cv=5,
    scoring='f1',
    n_jobs=-1
)

train_mean = train_scores.mean(axis=1)
val_mean = val_scores.mean(axis=1)

plt.figure(figsize=(10, 6))
plt.plot(train_sizes, train_mean, 'o-', label='Training F1')
plt.plot(train_sizes, val_mean, 'o-', label='Validation F1')
plt.xlabel('Training Set Size')
plt.ylabel('F1 Score')
plt.title('Learning Curve - Random Forest')
plt.grid(True)
plt.legend()
plt.show()
```

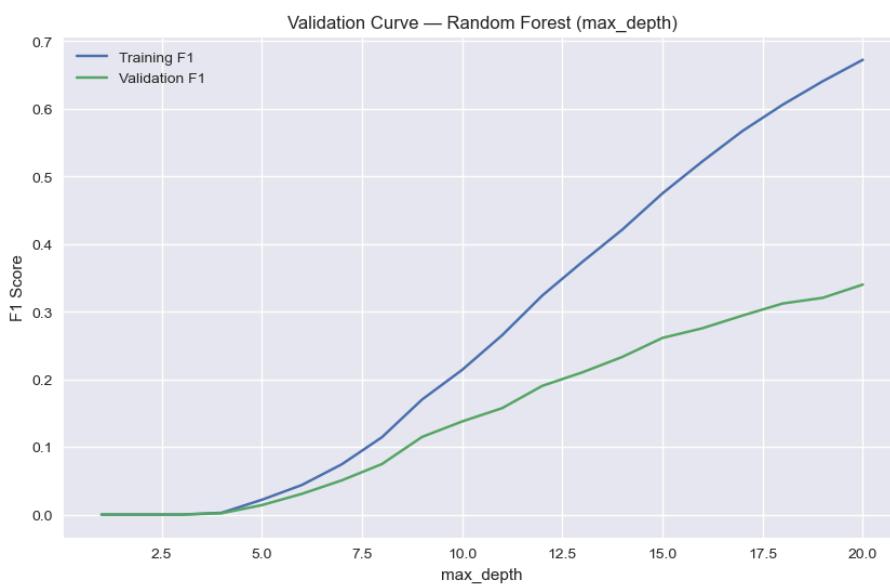


```
In [16]: from sklearn.model_selection import validation_curve
import numpy as np
import matplotlib.pyplot as plt

param_range = np.arange(1, 21)

train_scores, val_scores = validation_curve(
    models['RandomForest'],
    X, y,
    param_name='max_depth',
    param_range=param_range,
    cv=5,
    scoring='f1',
    n_jobs=-1
)

plt.figure(figsize=(10, 6))
plt.plot(param_range, train_scores.mean(axis=1), label='Training F1')
plt.plot(param_range, val_scores.mean(axis=1), label='Validation F1')
plt.xlabel('max_depth')
plt.ylabel('F1 Score')
plt.title('Validation Curve — Random Forest (max_depth)')
plt.grid(True)
plt.legend()
plt.show()
```



```
In [17]: from sklearn.metrics import precision_recall_curve, auc, average_precision_score
import matplotlib.pyplot as plt

model_choice = 'RandomForest'
# Assume:
#   y_test - the actual binary labels (0/1) for the test set
#   y_proba - the predicted probabilities for the positive class (model.predict_proba(X_test)[:,1])

# Compute precision/recall pairs for various thresholds
precision, recall, thresholds = precision_recall_curve(y_test, y_proba[model_choice])

# Compute average precision (PR-AUC)
pr_auc = average_precision_score(y_test, y_proba[model_choice])

# Compute area under the precision-recall curve (alternate)
pr_auc_trap = auc(recall, precision)

print(f"Average Precision (PR-AUC): {pr_auc:.3f}")
print(f"Area under PR-curve (by trapezoid): {pr_auc_trap:.3f}")
```

```

# Plot the precision-recall curve
plt.figure(figsize=(8, 6))
plt.step(recall, precision, where='post', label='Model')
plt.fill_between(recall, precision, step='post', alpha=0.2)

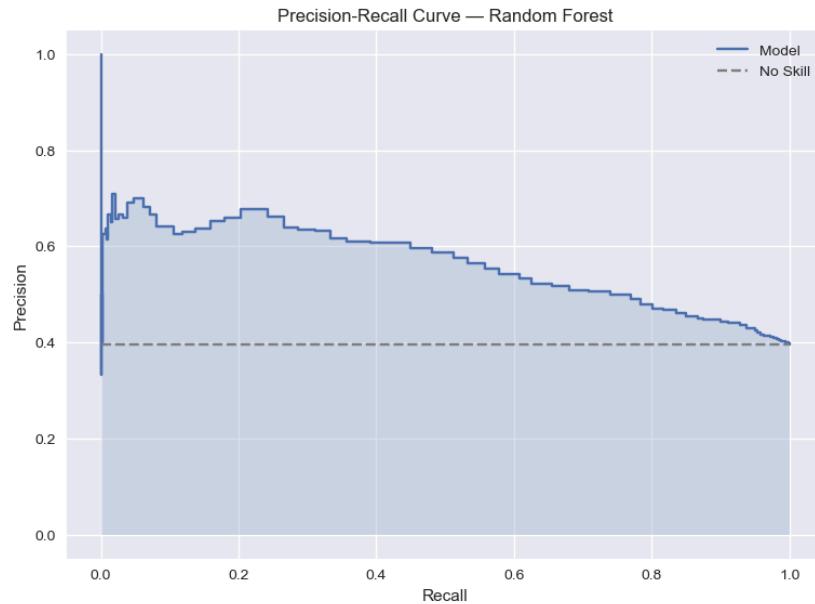
# Plot the no-skill line (precision equal to prevalence)
no_skill = sum(y_test==1) / len(y_test)
plt.hlines(no_skill, 0, 1, linestyle='--', color='grey', label='No Skill')

plt.xlabel('Recall')
plt.ylabel('Precision')
plt.title('Precision-Recall Curve — Random Forest')
plt.legend()
plt.grid(True)
plt.tight_layout()
plt.show()

```

Average Precision (PR-AUC): 0.566

Area under PR-curve (by trapezoid): 0.567



In []: