

Group X Progress Report: Heart Disease Prediction using Machine Learning

ZhiChong Lin, ZiDi Yao, Ke Ma

yaoz25@mcmaster.ca, mak11@mcmaster.ca, lin281@mcmaster.ca

1 Introduction

This section introduces the problem and motivation of your project. You may adapt the motivation from your original proposal. Typical content includes: (1) What problem you are solving, (2) Why it matters, (3) Why machine learning is suitable, (4) Your project objective. This should be about 0.25–0.5 pages.

2 Related Work

This section summarizes the most relevant previous work. If no identical problem exists, describe the most similar tasks such as: – Medical risk prediction – Heart disease datasets – Classic ML models like logistic regression / SVM in healthcare Cite at least five references (use custom.bib). Length: 0.25–0.5 pages.

3 Dataset and Preprocessing

Describe the dataset, number of samples, features, data source, and what preprocessing was required.

3.1 Dataset Description

Present the raw features in a table:

Feature	Description
Age	Age of patient (years)
Sex	Biological sex (M/F)
ChestPainType	Chest pain type (ATA, ASY, NAP, TA)
RestingBP	Resting blood pressure (mm Hg)
Cholesterol	Serum cholesterol (mg/dL)
FastingBS	Fasting blood sugar (0/1)
RestingECG	ECG results (Normal, ST, LVH)
MaxHR	Maximum heart rate achieved
ExerciseAngina	Exercise-induced angina (Y/N)
Oldpeak	ST depression value
ST_Slope	Slope of ST segment (Up/Flat/Down)
HeartDisease	Target label (1 = disease, 0 = healthy)

Table 1: Raw dataset features.

3.2 Target Extraction

Describe how HeartDisease was extracted as the binary label vector.

3.3 Feature Preprocessing

Explain your preprocessing:

- Removing whitespace in column names
- Encoding binary variables (Sex, ExerciseAngina, FastingBS)
- One-hot encoding for multi-class categorical features (ChestPainType, RestingECG, ST_Slope)
- Saved processed data to: processed/X_encoded.csv

3.4 Final Processed Dataset

State final shape (e.g., 918 rows \times 22 columns) and where it is stored.

4 Model Inputs (Features)

During our data preprocessing phase, we utilize `scikit-learn` built-in function `pipeline` to transform our data before feeding into Machine Learning Model. The dataset has both numerical and categorical features,

in the previous part we mentioned that for each numerical part we standardized them, while for categorical part we used one-hot encoding to transform them into vectors. In result, we have total 22 features after preprocessing, including 6 numerical features and 16 categorical features “(One-Hot Encoding)”. We then went ahead to further transform our data by using both features selection and dimensionality reduction techniques. Which is so called Chi-PCA method [1].

- **Chi-Square:** Since in Mathematically, the Chi-square statistic is defined as:

$$\chi^2 = \sum_i \sum_j \frac{(O_{ij} - E_{ij})^2}{E_{ij}}$$

, where O_{ij} is the observed frequency and E_{ij} is the expected frequency.

Therefore, It is expecting a positive value for frequency, so we use `MinMaxScaler` to scale all numerical features to $[0,1]$ range. So that all numerical features and categorical features are non-negative.

Then we have a Hyperparameters ‘k’ to select top k features with highest Chi-square statistic with respect to the target label. In here we set k=9, as we found that 9 is the best parameter after conducting grid-search.

- **PCA:** After feature selection, we then applied Principal Component Analysis (PCA) to reduce the dimensionality of the selected features. PCA works by identifying the directions (principal components) in which the data varies the most, and projecting the data onto these directions.

To determine the number of principal components to retain, we adopt the **Kaiser criterion** [2]. This rule suggests keeping only components with eigenvalues greater than 1.0.

After doing experiments of calculating eigenvalues for every single increase of principal components, we found that the first five components have eigenvalues greater than 1.0. Thus, we decided to retain five principal components for our final feature representation.

Hence, each patient sample is represented as a compact (data, 5) feature vector summarizing the most informative physiological and categorical characteristics. This final feature set is then used as input to our machine learning model.

5 Model Implementation

We have implemented a supervised learning pipeline for binary classification of heart disease presence. Our main model is a **Support Vector Machine (SVM)** with a **Radial Basis Function (RBF)** kernel, implemented using the `scikit-learn` library. This kernel choice allows the decision boundary to be nonlinear, which is important given the heterogeneous mixture of categorical and numerical medical features in the dataset.

Loss Function:

$$\min_{\mathbf{w}, b} \frac{1}{2} \|\mathbf{w}\|^2 + C \sum_{i=1}^n \max(0, 1 - y_i(\mathbf{w}^\top \phi(\mathbf{x}_i) + b))$$

where C is the penalty parameter controlling the trade-off between the margin size and misclassification tolerance, and $\phi(\cdot)$ denotes the nonlinear mapping induced by the **RBF Kernel**:

$$K(\mathbf{x}_i, \mathbf{x}_j) = \exp(-\gamma \|\mathbf{x}_i - \mathbf{x}_j\|^2)$$

The model was optimized using the `libsvm` implementation, which employs a coordinate descent solver with kernel caching for efficiency.

To evaluate our implementation, we compared SVM–RBF against two baseline models:

- **Logistic Regression:** This baseline model was chosen from kaggle, where the author didn't use features selection or dimensionality reduction, and he was able to achieve 85% accuracy.
- **Random Forest:** From this paper [1], the author has 98% accuracy by using Random Forest with Chi-PCA method. However, he used a 74 features and around 1000 datapoint of heartdisease dataset from UCL.

With SVM-RBF, we evaluate it's accuracy by using cross-validation, and we was only able to achieve 86% of accuracy.

We then use Random Forest and Logistic Regression as our model, Randomforest was able to achieve 87% accuracy, while Logistic Regression was able to achieve 85% accuracy.

Varies reason can be introduces in here, such as different dataset, the quality of dataset, or minor changes in the preprocessing phase that effect the data values meaning.

In future iterations, we plan to explore a **neural network architecture** (e.g., a multi-layer perceptron) to capture more complex feature interactions and potentially improve generalization performance. We also intent to change the detail in our preprocessing phase, such as using different order, or different preprocessing tools to present the data in a better way.

6 Evaluation Strategy and Results

6.1 Evaluation Method

Explain why you used stratified K-fold cross validation (e.g., small dataset size, need for robust evaluation).

6.2 Metrics

Explain why accuracy, precision, recall, F1, and AUC-ROC are important in medical diagnosis.

6.3 Results

Insert your figures:

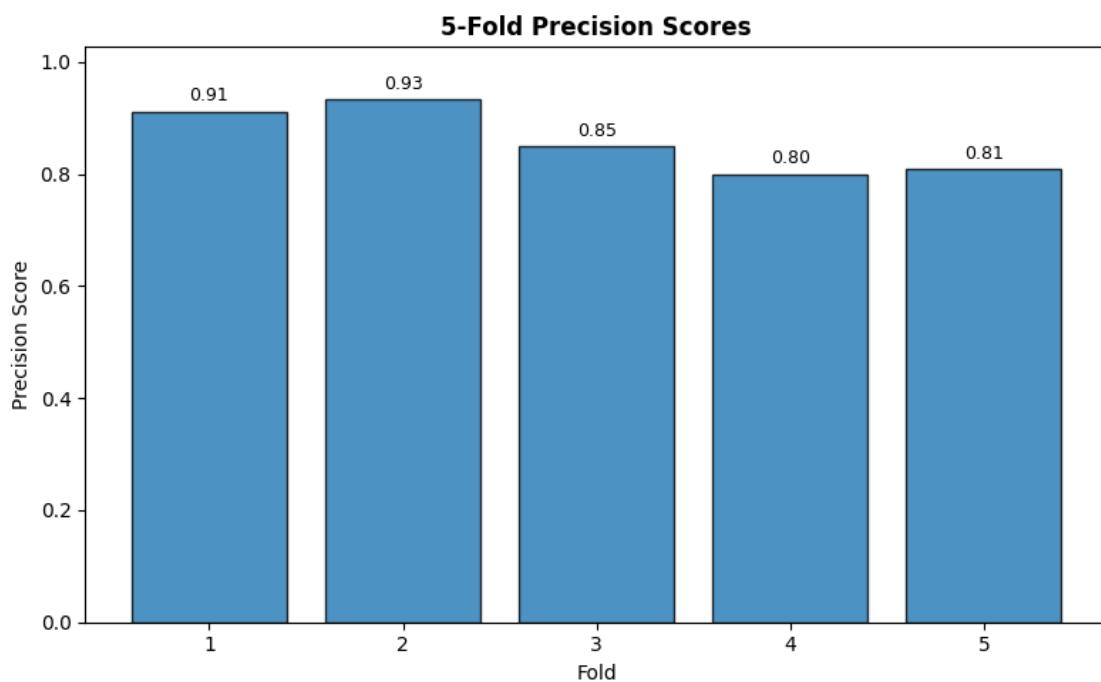


Figure 1: 5-fold precision scores.

7 Feedback and Future Plans

Summarize TA feedback and your improvements:

- Replace label encoding with one-hot encoding
- Consider switching from SVM to neural networks for performance gains
- Create a new GitHub branch for experiments

Team Contributions

Describe what each team member worked on.

```
===== K-Fold Cross Validation Results =====
Accuracy : 0.8616
Recall    : 0.8979
Precision: 0.8610
F1-score  : 0.8773
=====
```

Figure 2: Summary metrics across folds.

References

- [1] Anna Karen Gárate-Escamila, Amir Hajjam El Hassani, and Emmanuel Andrès. Classification models for heart disease prediction using feature selection and pca. *Informatics in Medicine Unlocked*, 19:100330, 2020.
- [2] Henry F. Kaiser. The application of electronic computers to factor analysis. *Educational and Psychological Measurement*, 20(1):141–151, 1960. Original work published 1960.

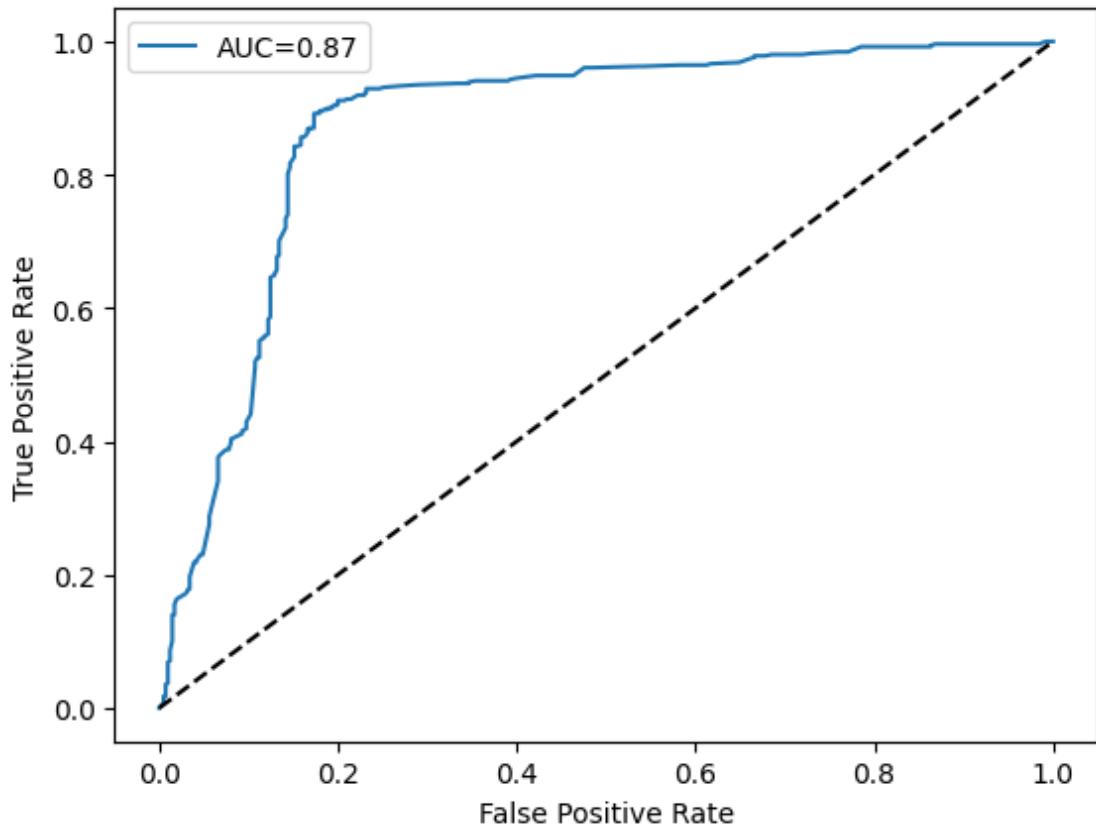


Figure 3: AUC–ROC curves.

Type I and Type II error graph

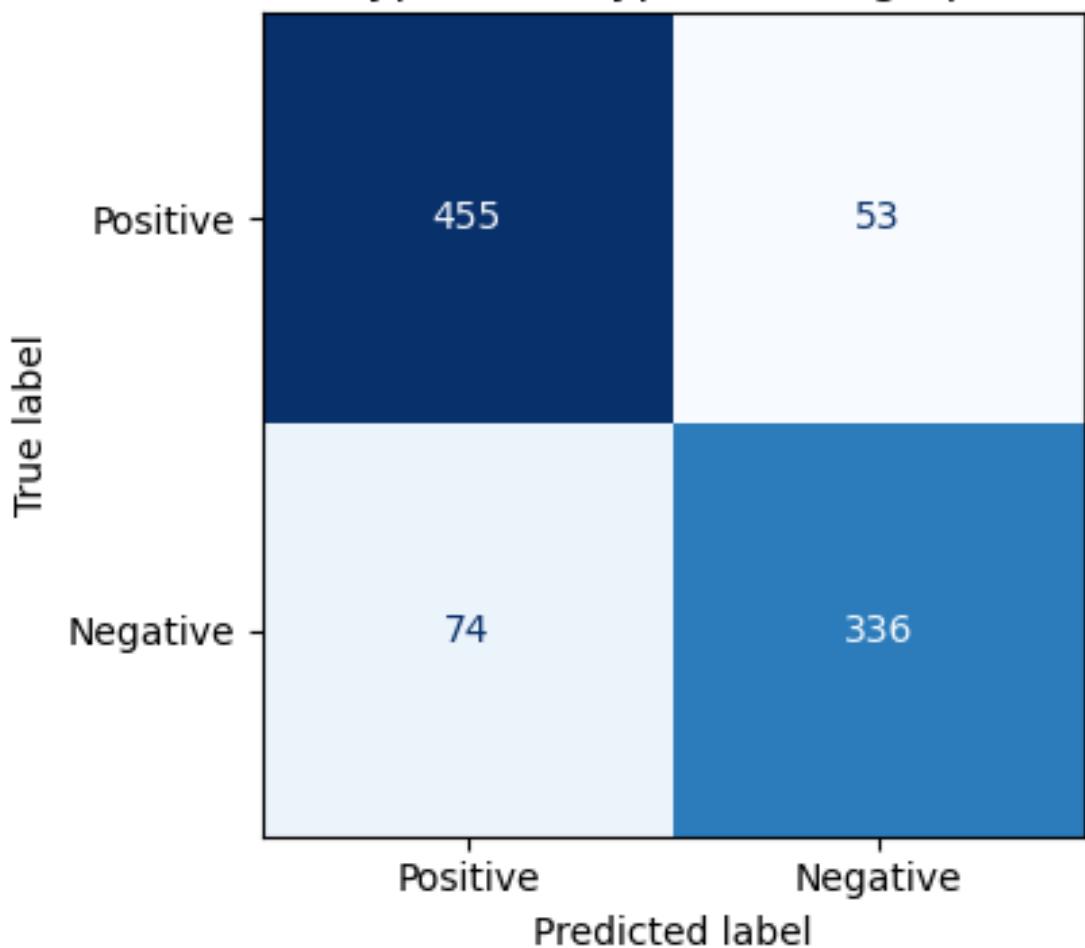


Figure 4: Confusion matrices.