

## ✓ TA Instructions

Hello! Welcome to Team 11's report. The checkpoints are labeled as such in the headers to make it easier for you to run, but everything has been commented out that is not necessary. The data access information is available in the "Data" section, and all dependencies / necessary downloads are shown in code.

Our github repo can be accessed here: <https://github.com/LoganB99/DL4H-SP24-Local-Explanations-For-Cervical-Cancer>

Our video overview can be accessed here:

Double-click (or enter) to edit

+ Code + Text

## ✓ Mount Notebook to Google Drive

To clear up clutter, the original FAQ and Attributions are in

[https://colab.research.google.com/drive/1MGxB\\_J2TvhAANcQG8VNMvOp1QdQrcxWb?authuser=1](https://colab.research.google.com/drive/1MGxB_J2TvhAANcQG8VNMvOp1QdQrcxWb?authuser=1)

```
import pandas as pd
from google.colab import drive
drive.mount('/content/drive', force_remount=True)

Mounted at /content/drive

#Testing
!pip install gspread google-auth
from google.colab import auth
auth.authenticate_user()

import gspread
from google.auth import default
creds, _ = default()

gc = gspread.authorize(creds)

Requirement already satisfied: gspread in /usr/local/lib/python3.10/dist-packages (6.0.2)
Requirement already satisfied: google-auth in /usr/local/lib/python3.10/dist-packages (2.27.0)
Requirement already satisfied: google-auth-oauthlib>=0.4.1 in /usr/local/lib/python3.10/dist-packages (from gspread) (1.2.0)
Requirement already satisfied: StrEnum==0.4.15 in /usr/local/lib/python3.10/dist-packages (from gspread) (0.4.15)
Requirement already satisfied: cachetools<6.0,>=2.0.0 in /usr/local/lib/python3.10/dist-packages (from google-auth) (5.3.3)
Requirement already satisfied: pyasn1-modules>=0.2.1 in /usr/local/lib/python3.10/dist-packages (from google-auth) (0.4.0)
Requirement already satisfied: rsa<5,>=3.1.4 in /usr/local/lib/python3.10/dist-packages (from google-auth) (4.9)
Requirement already satisfied: requests-oauthlib>=0.7.0 in /usr/local/lib/python3.10/dist-packages (from google-auth-oauthlib>=0.4.1->gspread)
Requirement already satisfied: pyasn1<0.7.0,>=0.4.6 in /usr/local/lib/python3.10/dist-packages (from pyasn1-modules>=0.2.1->google-auth) (0.4.6)
Requirement already satisfied: oauthlib>=3.0.0 in /usr/local/lib/python3.10/dist-packages (from requests-oauthlib>=0.7.0->google-auth-oauthlib)
Requirement already satisfied: requests>=2.0.0 in /usr/local/lib/python3.10/dist-packages (from requests-oauthlib>=0.7.0->google-auth-oauthlib)
Requirement already satisfied: charset-normalizer<4,>=2 in /usr/local/lib/python3.10/dist-packages (from requests>=2.0.0->requests-oauthlib)
Requirement already satisfied: idna<4,>=2.5 in /usr/local/lib/python3.10/dist-packages (from requests>=2.0.0->requests-oauthlib>=0.7.0->google-auth-oauthlib)
Requirement already satisfied: urllib3<3,>=1.21.1 in /usr/local/lib/python3.10/dist-packages (from requests>=2.0.0->requests-oauthlib>=0.7.0->google-auth-oauthlib)
Requirement already satisfied: certifi>=2017.4.17 in /usr/local/lib/python3.10/dist-packages (from requests>=2.0.0->requests-oauthlib>=0.7.0->google-auth-oauthlib)
```

## Introduction

- Background of the problem

Cervical Cancer prediction is a prevalent and necessary problem within today's healthcare system. Specifically, researchers are working towards identifying risk factors and potential causes for cervical cancer. Current models, however, cannot explain why a decision is made. Local explainability techniques have been developed aiming to the causes and effects of changes within a model and explain the decision-making process at an individual prediction level, but may not be applicable in every scenario, and the explanations are not always consistent or faithful. Consequently, clinicians cannot explain why a model selected a patient as low or high risk through black-box magic models.

- Paper explanation

The paper aims to combat the current problem of ambiguity in explainability across scenarios and analyze the existing local interpretability methods to propose methods to help clinicians determine which type of explanation models to use in a given context. Specifically, the researchers tested 5 different ML algorithms to identify the model with the highest disease prediction accuracy, and then applied explainability methods to the model to identify the best practice for disease prediction. The paper then uses the predictions of the best model to generate explanations for each model across popular interpretability methods. These methods include LIME, SHAP, Diverse Counterfactual Explanations, Tree Interpreter, and Local Surrogates. Finally, each of the interpretability methods are evaluated on a set of metrics. The model found that LIME is the most robust explainability method, but no single explanation performance optimally across all metrics. Therefore, the researchers suggest that clinicians should choose a method based on the setting or choose a weighted sum of metrics. This approach helps satisfy the desired explainability properties when determining patient risk in cervical cancer. As a result, the

paper also recommends and influences future models to consider interpretability methods in their analysis to improve trust in the new world of generative and predictive models.

## Scope of Reproducibility:

We aim to reproduce the results of the model using the UCI dataset and suggested models. We will use ADASYN to balance the dataset and remove and retrain features as one of our ablations. As another ablation, we want to test the model on the unbalanced dataset.

1. Hypothesis 1: Random Forest is the most performing model in predicting cervical cancer in terms of AUC.
2. Hypothesis 2: LIME is the most robust explainability model shown by the ROAR (remove and retrain) faithfulness metric.

## ✓ Methodology

Python version in notebook: 3.10.12

## ✓ Checkpoint: Dependencies

Note: because of Colab's default setup, you may have to restart the notebook and rerun after installing packages.

```
# External package installation
!pip install pandas
!pip install kaleido
!pip install gdown==4.6.0
!pip install shap
!pip install lime
!pip install interpret-community
!pip install alibi
!pip install treeinterpreter
!pip install SALib
!pip install dice-ml
!pip install pip install spectralcluster
!pip install kaleido
!pip install requests
!pip install shapash
```

```

Requirement already satisfied: pandas in /usr/local/lib/python3.10/dist-packages (2.0.3)
Requirement already satisfied: python-dateutil>=2.8.2 in /usr/local/lib/python3.10/dist-packages (from pandas) (2.8.2)
Requirement already satisfied: pytz>=2020.1 in /usr/local/lib/python3.10/dist-packages (from pandas) (2023.4)
Requirement already satisfied: tzdata>=2022.1 in /usr/local/lib/python3.10/dist-packages (from pandas) (2024.1)
Requirement already satisfied: numpy>=1.21.0 in /usr/local/lib/python3.10/dist-packages (from pandas) (1.25.2)
Requirement already satisfied: six>=1.5 in /usr/local/lib/python3.10/dist-packages (from python-dateutil>=2.8.2->pandas) (1.16.0)
Collecting kaleido
  Downloading kaleido-0.2.1-py2.py3-none-manylinux1_x86_64.whl (79.9 MB)
  79.9/79.9 MB 7.8 MB/s eta 0:00:00
Installing collected packages: kaleido
Successfully installed kaleido-0.2.1
Collecting gdown==4.6.0
  Downloading gdown-4.6.0-py3-none-any.whl (14 kB)
Requirement already satisfied: filelock in /usr/local/lib/python3.10/dist-packages (from gdown==4.6.0) (3.14.0)
Requirement already satisfied: requests[socks] in /usr/local/lib/python3.10/dist-packages (from gdown==4.6.0) (2.31.0)
Requirement already satisfied: six in /usr/local/lib/python3.10/dist-packages (from gdown==4.6.0) (1.16.0)
Requirement already satisfied: tqdm in /usr/local/lib/python3.10/dist-packages (from gdown==4.6.0) (4.66.2)
Requirement already satisfied: beautifulsoup4 in /usr/local/lib/python3.10/dist-packages (from gdown==4.6.0) (4.12.3)
Requirement already satisfied: soupsieve>1.2 in /usr/local/lib/python3.10/dist-packages (from beautifulsoup4->gdown==4.6.0) (2.5)
Requirement already satisfied: charset-normalizer<4,>=2 in /usr/local/lib/python3.10/dist-packages (from requests[socks]->gdown==4.6.0) (3)
Requirement already satisfied: idna<4,>=2.5 in /usr/local/lib/python3.10/dist-packages (from requests[socks]->gdown==4.6.0) (3.7)
Requirement already satisfied: urllib3<3,>=1.21.1 in /usr/local/lib/python3.10/dist-packages (from requests[socks]->gdown==4.6.0) (2.0.7)
Requirement already satisfied: certifi>=2017.4.17 in /usr/local/lib/python3.10/dist-packages (from requests[socks]->gdown==4.6.0) (2024.2.)
Requirement already satisfied: PySocks!=1.5.7,>=1.5.6 in /usr/local/lib/python3.10/dist-packages (from requests[socks]->gdown==4.6.0) (1.7)
Installing collected packages: gdown
  Attempting uninstall: gdown
    Found existing installation: gdown 5.1.0
    Uninstalling gdown-5.1.0:
      Successfully uninstalled gdown-5.1.0
Successfully installed gdown-4.6.0
Collecting shap
  Downloading shap-0.45.0-cp310-cp310-manylinux_2_12_x86_64.manylinux2010_x86_64.manylinux_2_17_x86_64.manylinux2014_x86_64.whl (538 kB)
  538.2/538.2 kB 6.4 MB/s eta 0:00:00
Requirement already satisfied: numpy in /usr/local/lib/python3.10/dist-packages (from shap) (1.25.2)
Requirement already satisfied: scipy in /usr/local/lib/python3.10/dist-packages (from shap) (1.11.4)
Requirement already satisfied: scikit-learn in /usr/local/lib/python3.10/dist-packages (from shap) (1.2.2)
Requirement already satisfied: pandas in /usr/local/lib/python3.10/dist-packages (from shap) (2.0.3)
Requirement already satisfied: tqdm>=4.27.0 in /usr/local/lib/python3.10/dist-packages (from shap) (4.66.2)
Requirement already satisfied: packaging>20.9 in /usr/local/lib/python3.10/dist-packages (from shap) (24.0)
Collecting slicer==0.0.7 (from shap)
  Downloading slicer-0.0.7-py3-none-any.whl (14 kB)
Requirement already satisfied: numba in /usr/local/lib/python3.10/dist-packages (from shap) (0.58.1)
Requirement already satisfied: cloudpickle in /usr/local/lib/python3.10/dist-packages (from shap) (2.2.1)
Requirement already satisfied: llvmlite<0.42,>=0.41.0dev0 in /usr/local/lib/python3.10/dist-packages (from numba->shap) (0.41.1)
Requirement already satisfied: python-dateutil>=2.8.2 in /usr/local/lib/python3.10/dist-packages (from pandas->shap) (2.8.2)
Requirement already satisfied: pytz>=2020.1 in /usr/local/lib/python3.10/dist-packages (from pandas->shap) (2023.4)
Requirement already satisfied: tzdata>=2022.1 in /usr/local/lib/python3.10/dist-packages (from pandas->shap) (2024.1)
Requirement already satisfied: joblib>=1.1.1 in /usr/local/lib/python3.10/dist-packages (from scikit-learn->shap) (1.4.0)
Requirement already satisfied: threadpoolctl>=2.0.0 in /usr/local/lib/python3.10/dist-packages (from scikit-learn->shap) (3.5.0)
Requirement already satisfied: six>=1.5 in /usr/local/lib/python3.10/dist-packages (from python-dateutil>=2.8.2->pandas->shap) (1.16.0)
Installing collected packages: slicer, shap
Successfully installed shap-0.45.0 slicer-0.0.7
Collecting lime
  Downloading lime-0.2.0.1.tar.gz (275 kB)
  275.7/275.7 kB 4.4 MB/s eta 0:00:00
  Preparing metadata (setup.py) ... done
Requirement already satisfied: matplotlib in /usr/local/lib/python3.10/dist-packages (from lime) (3.7.1)
Requirement already satisfied: numpy in /usr/local/lib/python3.10/dist-packages (from lime) (1.25.2)
Requirement already satisfied: scipy in /usr/local/lib/python3.10/dist-packages (from lime) (1.11.4)
Requirement already satisfied: tqdm in /usr/local/lib/python3.10/dist-packages (from lime) (4.66.2)
Requirement already satisfied: scikit-learn<=0.18 in /usr/local/lib/python3.10/dist-packages (from lime) (1.2.2)
Requirement already satisfied: scikit-image>=0.12 in /usr/local/lib/python3.10/dist-packages (from lime) (0.19.3)
Requirement already satisfied: networkx>>2.2 in /usr/local/lib/python3.10/dist-packages (from scikit-image>=0.12->lime) (3.3)
Requirement already satisfied: pillow!=7.1.0,!=7.1.1,!=8.3.0,>=6.1.0 in /usr/local/lib/python3.10/dist-packages (from scikit-image>=0.12->lime) (3.1.6)
Requirement already satisfied: imageio>=2.4.1 in /usr/local/lib/python3.10/dist-packages (from scikit-image>=0.12->lime) (2.31.6)
Requirement already satisfied: tifffile>>2019.7.26 in /usr/local/lib/python3.10/dist-packages (from scikit-image>=0.12->lime) (2024.4.24)
Requirement already satisfied: PyWavelets=1.1.1 in /usr/local/lib/python3.10/dist-packages (from scikit-image>=0.12->lime) (1.6.0)
Requirement already satisfied: packaging>=20.0 in /usr/local/lib/python3.10/dist-packages (from scikit-image>=0.12->lime) (24.0)
Requirement already satisfied: joblib>=1.1.1 in /usr/local/lib/python3.10/dist-packages (from scikit-learn>=0.18->lime) (1.4.0)
Requirement already satisfied: threadpoolctl>=2.0.0 in /usr/local/lib/python3.10/dist-packages (from scikit-learn>=0.18->lime) (3.5.0)
Requirement already satisfied: contourpy>=1.0.1 in /usr/local/lib/python3.10/dist-packages (from matplotlib->lime) (1.2.1)
Requirement already satisfied: cycler>=0.10 in /usr/local/lib/python3.10/dist-packages (from matplotlib->lime) (0.12.1)
Requirement already satisfied: fonttools>=4.22.0 in /usr/local/lib/python3.10/dist-packages (from matplotlib->lime) (4.51.0)
Requirement already satisfied: kiwisolver>=1.0.1 in /usr/local/lib/python3.10/dist-packages (from matplotlib->lime) (1.4.5)
Requirement already satisfied: pyparsing>=2.3.1 in /usr/local/lib/python3.10/dist-packages (from matplotlib->lime) (3.1.2)
Requirement already satisfied: python-dateutil>=2.7 in /usr/local/lib/python3.10/dist-packages (from matplotlib->lime) (2.8.2)
Requirement already satisfied: six>=1.5 in /usr/local/lib/python3.10/dist-packages (from python-dateutil>=2.7->matplotlib->lime) (1.16.0)
Building wheels for collected packages: lime
  Building wheel for lime (setup.py) ... done
  Created wheel for lime: filename=lime-0.2.0.1-py3-none-any.whl size=283835 sha256=7533a61cd7eb878f8effe1be31487be017f23ad52ddd9852d958d6:
  Stored in directory: /root/.cache/pip/wheels/fd/a2/af/9ac0a1a85a27f314a06b39e1f492bee1547d52549a4606ed89
Successfully built lime
Installing collected packages: lime
Successfully installed lime-0.2.0.1
Collecting interpret-community
  Downloading interpret_community-0.31.0-py3-none-any.whl (130 kB)
  130.7/130.7 kB 3.3 MB/s eta 0:00:00
Requirement already satisfied: numpy in /usr/local/lib/python3.10/dist-packages (from interpret-community) (1.25.2)
Collecting pandas<2.0.0 (from interpret-community)
  Downloading pandas-1.5.3-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (12.1 MB)
  12.1/12.1 MB 26.6 MB/s eta 0:00:00
Requirement already satisfied: scipy in /usr/local/lib/python3.10/dist-packages (from interpret-community) (1.11.4)
Collecting ml-wrappers<=0.5.4 (from interpret-community)
  Downloading ml_wrappers-0.5.5-py3-none-any.whl (51 kB)

```

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51.9/51.9 kB 6.2 MB/s eta 0:00:00
Requirement already satisfied: scikit-learn in /usr/local/lib/python3.10/dist-packages (from interpret-community) (1.2.2)
Requirement already satisfied: packaging in /usr/local/lib/python3.10/dist-packages (from interpret-community) (24.0)
Collecting shap<=0.44.0,>=0.20.0 (from interpret-community)
  Downloading shap-0.44.0-cp310-cp310-manylinux2_12_x86_64.manylinux2010_x86_64.manylinux2_17_x86_64.manylinux2014_x86_64.whl (533 kB)
   533.5/533.5 kB 39.9 MB/s eta 0:00:00
Collecting raiutils~=0.4.0 (from interpret-community)
  Downloading raiutils-0.4.2-py3-none-any.whl (17 kB)
Collecting interpret-core<=0.5.0,>=0.1.20 (from interpret-community)
  Downloading interpret_core-0.5.0-py3-none-any.whl (15.8 MB)
   15.8/15.8 kB 51.6 MB/s eta 0:00:00
Requirement already satisfied: joblib=>0.11 in /usr/local/lib/python3.10/dist-packages (from interpret-core<=0.5.0,>=0.1.20->interpret-community)
Requirement already satisfied: python-dateutil>=2.8.1 in /usr/local/lib/python3.10/dist-packages (from pandas<2.0.0->interpret-community)
Requirement already satisfied: pytz>=2020.1 in /usr/local/lib/python3.10/dist-packages (from pandas<2.0.0->interpret-community) (2023.4)
Requirement already satisfied: requests in /usr/local/lib/python3.10/dist-packages (from raiutils~=0.4.0->interpret-community) (2.31.0)
Requirement already satisfied: threadpoolctl>=2.0.0 in /usr/local/lib/python3.10/dist-packages (from scikit-learn->interpret-community) (3)
Requirement already satisfied: tqdm>=4.27.0 in /usr/local/lib/python3.10/dist-packages (from shap<=0.44.0,>=0.20.0->interpret-community) (4)
Requirement already satisfied: slicer=>0.7 in /usr/local/lib/python3.10/dist-packages (from shap<=0.44.0,>=0.20.0->interpret-community)
Requirement already satisfied: numba in /usr/local/lib/python3.10/dist-packages (from shap<=0.44.0,>=0.20.0->interpret-community) (0.58.1)
Requirement already satisfied: cloudpickle in /usr/local/lib/python3.10/dist-packages (from shap<=0.44.0,>=0.20.0->interpret-community) (2)
Requirement already satisfied: six>=1.5 in /usr/local/lib/python3.10/dist-packages (from python-dateutil>=2.8.1->pandas<2.0.0->interpret-community)
Requirement already satisfied: llvmlite<0.42,>=0.41.0dev0 in /usr/local/lib/python3.10/dist-packages (from numba->shap<=0.44.0,>=0.20.0->interpret-community)
Requirement already satisfied: charset-normalizer<4,>=2 in /usr/local/lib/python3.10/dist-packages (from requests->raiutils~=0.4.0->interpret-community)
Requirement already satisfied: idna<4,>=2.5 in /usr/local/lib/python3.10/dist-packages (from requests->raiutils~=0.4.0->interpret-community)
Requirement already satisfied: urllib3<3,>=1.21.1 in /usr/local/lib/python3.10/dist-packages (from requests->raiutils~=0.4.0->interpret-community)
Requirement already satisfied: certifi>=2017.4.17 in /usr/local/lib/python3.10/dist-packages (from requests->raiutils~=0.4.0->interpret-community)
Installing collected packages: pandas, shap, raiutils, ml-wrappers, interpret-core, interpret-community
Attempting uninstall: pandas
  Found existing installation: pandas 2.0.3
  Uninstalling pandas-2.0.3:
    Successfully uninstalled pandas-2.0.3
Attempting uninstall: shap
  Found existing installation: shap 0.45.0
  Uninstalling shap-0.45.0:
    Successfully uninstalled shap-0.45.0
ERROR: pip's dependency resolver does not currently take into account all the packages that are installed. This behaviour is the source of google-colab 1.0.0 requires pandas==2.0.3, but you have pandas 1.5.3 which is incompatible.
Successfully installed interpret-community-0.31.0 interpret-core-0.5.0 ml-wrappers-0.5.5 pandas-1.5.3 raiutils-0.4.2 shap-0.44.0
Collecting alibi
  Downloading alibi-0.9.6-py3-none-any.whl (522 kB)
   522.1/522.1 kB 6.9 MB/s eta 0:00:00
Requirement already satisfied: numpy<2.0.0,>=1.16.2 in /usr/local/lib/python3.10/dist-packages (from alibi) (1.25.2)
Requirement already satisfied: pandas<3.0.0,>=1.0.0 in /usr/local/lib/python3.10/dist-packages (from alibi) (1.5.3)
Requirement already satisfied: scikit-learn<2.0.0,>=1.0.0 in /usr/local/lib/python3.10/dist-packages (from alibi) (1.2.2)
Requirement already satisfied: spacy[lookups]<4.0.0,>=2.0.0 in /usr/local/lib/python3.10/dist-packages (from alibi) (3.7.4)
Requirement already satisfied: blis<0.8.0 in /usr/local/lib/python3.10/dist-packages (from alibi) (0.7.11)
Requirement already satisfied: scikit-image<0.23,>=0.17.2 in /usr/local/lib/python3.10/dist-packages (from alibi) (0.19.3)
Requirement already satisfied: requests<3.0.0,>=2.21.0 in /usr/local/lib/python3.10/dist-packages (from alibi) (2.31.0)
Requirement already satisfied: Pillow<11.0,>=5.4.1 in /usr/local/lib/python3.10/dist-packages (from alibi) (9.4.0)
Requirement already satisfied: attrs<24.0.0,>=19.2.0 in /usr/local/lib/python3.10/dist-packages (from alibi) (23.2.0)
Requirement already satisfied: scipy<2.0.0,>=1.1.0 in /usr/local/lib/python3.10/dist-packages (from alibi) (1.11.4)
Requirement already satisfied: matplotlib<4.0.0,>=3.0.0 in /usr/local/lib/python3.10/dist-packages (from alibi) (3.7.1)
Requirement already satisfied: typing-extensions>=3.7.4.3 in /usr/local/lib/python3.10/dist-packages (from alibi) (4.11.0)
Collecting dill<0.4.0,>=0.3.0 (from alibi)
  Downloading dill-0.3.8-py3-none-any.whl (116 kB)
   116.3/116.3 kB 9.1 MB/s eta 0:00:00
Requirement already satisfied: transformers<5.0.0,>=4.7.0 in /usr/local/lib/python3.10/dist-packages (from alibi) (4.40.1)
Requirement already satisfied: tqdm<5.0.0,>=4.28.1 in /usr/local/lib/python3.10/dist-packages (from alibi) (4.66.2)
Requirement already satisfied: contourpy>=1.0.1 in /usr/local/lib/python3.10/dist-packages (from matplotlib<4.0.0,>=3.0.0->alibi) (1.2.1)
Requirement already satisfied: cycler>=1.0 in /usr/local/lib/python3.10/dist-packages (from matplotlib<4.0.0,>=3.0.0->alibi) (0.12.1)
Requirement already satisfied: fonttools>=4.22.0 in /usr/local/lib/python3.10/dist-packages (from matplotlib<4.0.0,>=3.0.0->alibi) (4.51.0)
Requirement already satisfied: kiwisolver>=1.0.1 in /usr/local/lib/python3.10/dist-packages (from matplotlib<4.0.0,>=3.0.0->alibi) (1.4.5)
Requirement already satisfied: packaging>=20.0 in /usr/local/lib/python3.10/dist-packages (from matplotlib<4.0.0,>=3.0.0->alibi) (24.0)
Requirement already satisfied: pyparsing>=2.3.1 in /usr/local/lib/python3.10/dist-packages (from matplotlib<4.0.0,>=3.0.0->alibi) (3.1.2)
Requirement already satisfied: python-dateutil>=2.7 in /usr/local/lib/python3.10/dist-packages (from matplotlib<4.0.0,>=3.0.0->alibi) (2.8)
Requirement already satisfied: pytz>=2020.1 in /usr/local/lib/python3.10/dist-packages (from pandas<3.0.0,>=1.0.0->alibi) (2023.4)
Requirement already satisfied: charset-normalizer<4,>=2 in /usr/local/lib/python3.10/dist-packages (from requests<3.0.0,>=2.21.0->alibi) (4)
Requirement already satisfied: idna<4,>=2.5 in /usr/local/lib/python3.10/dist-packages (from requests<3.0.0,>=2.21.0->alibi) (3.7)
Requirement already satisfied: urllib3<3,>=1.21.1 in /usr/local/lib/python3.10/dist-packages (from requests<3.0.0,>=2.21.0->alibi) (2.0.7)
Requirement already satisfied: certifi>=2017.4.17 in /usr/local/lib/python3.10/dist-packages (from requests<3.0.0,>=2.21.0->alibi) (2024.2)
Requirement already satisfied: networkx>=2.2 in /usr/local/lib/python3.10/dist-packages (from scikit-image<0.23,>=0.17.2->alibi) (3.3)
Requirement already satisfied: imageio>=2.4.1 in /usr/local/lib/python3.10/dist-packages (from scikit-image<0.23,>=0.17.2->alibi) (2.31.6)
Requirement already satisfied: tifffile>=2019.7.26 in /usr/local/lib/python3.10/dist-packages (from scikit-image<0.23,>=0.17.2->alibi) (20)
Requirement already satisfied: PyWavelets>=1.1.1 in /usr/local/lib/python3.10/dist-packages (from scikit-image<0.23,>=0.17.2->alibi) (1.6.1)
Requirement already satisfied: joblib>=1.1.1 in /usr/local/lib/python3.10/dist-packages (from scikit-learn<2.0.0,>=1.0.0->alibi) (1.4.0)
Requirement already satisfied: threadpoolctl>=2.0.0 in /usr/local/lib/python3.10/dist-packages (from scikit-learn<2.0.0,>=1.0.0->alibi) (3)
Requirement already satisfied: spacy-legacy<3.1.0,>=3.0.11 in /usr/local/lib/python3.10/dist-packages (from spacy[lookups]<4.0.0,>=2.0.0->alibi) (4)
Requirement already satisfied: spacy-loggers<2.0,>=1.0.0 in /usr/local/lib/python3.10/dist-packages (from spacy[lookups]<4.0.0,>=2.0.0->alibi) (4)
Requirement already satisfied: murmurhash<1.1.0,>=0.28.0 in /usr/local/lib/python3.10/dist-packages (from spacy[lookups]<4.0.0,>=2.0.0->alibi) (4)
Requirement already satisfied: cymem<2.1.0,>=2.0.2 in /usr/local/lib/python3.10/dist-packages (from spacy[lookups]<4.0.0,>=2.0.0->alibi) (4)
Requirement already satisfied: preshed<3.1.0,>=3.0.2 in /usr/local/lib/python3.10/dist-packages (from spacy[lookups]<4.0.0,>=2.0.0->alibi) (4)
Requirement already satisfied: thinc<8.3.0,>=8.2.2 in /usr/local/lib/python3.10/dist-packages (from spacy[lookups]<4.0.0,>=2.0.0->alibi) (4)
Requirement already satisfied: wasabi<1.2.0,>=0.9.1 in /usr/local/lib/python3.10/dist-packages (from spacy[lookups]<4.0.0,>=2.0.0->alibi) (4)
Requirement already satisfied: srslly<3.0.0,>=2.4.3 in /usr/local/lib/python3.10/dist-packages (from spacy[lookups]<4.0.0,>=2.0.0->alibi) (4)
Requirement already satisfied: catalogue<2.1.0,>=2.0.6 in /usr/local/lib/python3.10/dist-packages (from spacy[lookups]<4.0.0,>=2.0.0->alibi) (4)
Requirement already satisfied: weasel<4.0,>=0.1.0 in /usr/local/lib/python3.10/dist-packages (from spacy[lookups]<4.0.0,>=2.0.0->alibi) (4)
Requirement already satisfied: typer<0.10.0,>=0.3.0 in /usr/local/lib/python3.10/dist-packages (from spacy[lookups]<4.0.0,>=2.0.0->alibi) (4)
Requirement already satisfied: smart-open<7.0.0,>=5.2.1 in /usr/local/lib/python3.10/dist-packages (from spacy[lookups]<4.0.0,>=2.0.0->alibi) (4)
Requirement already satisfied: pydantic!=1.8,!=1.8.1,<3.0.0,>=1.7.4 in /usr/local/lib/python3.10/dist-packages (from spacy[lookups]<4.0.0,>=2.0.0->alibi) (4)
Requirement already satisfied: jinja2 in /usr/local/lib/python3.10/dist-packages (from spacy[lookups]<4.0.0,>=2.0.0->alibi) (3.1.3)
Requirement already satisfied: setuptools in /usr/local/lib/python3.10/dist-packages (from spacy[lookups]<4.0.0,>=2.0.0->alibi) (67.7.2)
Requirement already satisfied: langcodes<4.0.0,>=3.2.0 in /usr/local/lib/python3.10/dist-packages (from spacy[lookups]<4.0.0,>=2.0.0->alibi) (4)
Collecting spacy-lookups-data<1.1.0,>=1.0.3 (from spacy[lookups]<4.0.0,>=2.0.0->alibi)
  Downloading spacy_lookups_data-1.0.5-py3-none-any.whl (98.5 MB)

```

98.5/98.5 MB 9.8 MB/s eta 0:00:00

Requirement already satisfied: filelock in /usr/local/lib/python3.10/dist-packages (from transformers<5.0.0,>=4.7.0->alibi) (3.14.0)  
 Requirement already satisfied: huggingface-hub<1.0,>=0.19.3 in /usr/local/lib/python3.10/dist-packages (from transformers<5.0.0,>=4.7.0->alibi) (6.0.1)  
 Requirement already satisfied: pyyaml<=5.1 in /usr/local/lib/python3.10/dist-packages (from transformers<5.0.0,>=4.7.0->alibi) (6.0.1)  
 Requirement already satisfied: regex<=2019.12.17 in /usr/local/lib/python3.10/dist-packages (from transformers<5.0.0,>=4.7.0->alibi) (2023)  
 Requirement already satisfied: tokenizers<0.20,>=0.19 in /usr/local/lib/python3.10/dist-packages (from transformers<5.0.0,>=4.7.0->alibi) (0.4)  
 Requirement already satisfied: safetensors>=0.4.1 in /usr/local/lib/python3.10/dist-packages (from transformers<5.0.0,>=4.7.0->alibi) (0.4)  
 Requirement already satisfied: fsspec>=2023.5.0 in /usr/local/lib/python3.10/dist-packages (from huggingface-hub<1.0,>=0.19.3->transformer:  
 Requirement already satisfied: language-data==1.2 in /usr/local/lib/python3.10/dist-packages (from langcodes<4.0.0,>=3.2.0->spacy[lookups]:  
 Requirement already satisfied: annotated-types>=0.4.0 in /usr/local/lib/python3.10/dist-packages (from pydantic!=1.8,!>=1.8.1,<3.0.0,>=1.7..  
 Requirement already satisfied: pydantic-core==2.18.2 in /usr/local/lib/python3.10/dist-packages (from pydantic!=1.8,!>=1.8.1,<3.0.0,>=1.7.4..  
 Requirement already satisfied: six>=1.5 in /usr/local/lib/python3.10/dist-packages (from python-dateutil>=2.7->matplotlib<4.0.0,>=3.0.0->alibi:  
 Requirement already satisfied: confection<1.0.0,>=0.0.1 in /usr/local/lib/python3.10/dist-packages (from thinc<8.3.0,>=8.2.2->spacy[lookups]:  
 Requirement already satisfied: click<9.0.0,>=7.1.1 in /usr/local/lib/python3.10/dist-packages (from typer<0.10.0,>=0.3.0->spacy[lookups]<4..  
 Requirement already satisfied: cloudpathlib<0.17.0,>=0.7.0 in /usr/local/lib/python3.10/dist-packages (from weasel<0.4.0,>=0.1.0->spacy[lookups]:  
 Requirement already satisfied: MarkupSafe>=2.0 in /usr/local/lib/python3.10/dist-packages (from jinja2->spacy[lookups]<4.0.0,>=2.0.0->alibi:  
 Requirement already satisfied: marisa-trie>=0.7.7 in /usr/local/lib/python3.10/dist-packages (from language-data>=1.2->langcodes<4.0.0,>=3..  
 Installing collected packages: spacy-lookups-data, dill, alibi  
 Successfully installed alibi-0.9.6 dill-0.3.8 spacy-lookups-data-1.0.5

Collecting treeinterpreter

Downloading treeinterpreter-0.2.3-py2.py3-none-any.whl (6.0 kB)

Installing collected packages: treeinterpreter

Successfully installed treeinterpreter-0.2.3

Collecting SALib

Downloading salib-1.5.0-py3-none-any.whl (778 kB)

778.8/778.8 KB 8.0 MB/s eta 0:00:00

Requirement already satisfied: matplotlib&gt;=3.5 in /usr/local/lib/python3.10/dist-packages (from SALib) (3.7.1)

Collecting multiprocess (from SALib)

Downloading multiprocess-0.70.16-py310-none-any.whl (134 kB)

134.8/134.8 KB 11.6 MB/s eta 0:00:00

Requirement already satisfied: numpy&gt;=1.20.3 in /usr/local/lib/python3.10/dist-packages (from SALib) (1.25.2)

Collecting pandas&gt;=2.0 (from SALib)

Downloading pandas-2.2.2-cp310-cp310-manylinux\_2\_17\_x86\_64.manylinux2014\_x86\_64.whl (13.0 MB)

13.0/13.0 MB 31.6 MB/s eta 0:00:00

Requirement already satisfied: scipy&gt;=1.9.3 in /usr/local/lib/python3.10/dist-packages (from SALib) (1.11.4)

Requirement already satisfied: contourpy&gt;=1.0.1 in /usr/local/lib/python3.10/dist-packages (from matplotlib&gt;=3.5-&gt;SALib) (1.2.1)

Requirement already satisfied: cycler&gt;=0.10 in /usr/local/lib/python3.10/dist-packages (from matplotlib&gt;=3.5-&gt;SALib) (0.12.1)

Requirement already satisfied: fonttools&gt;=4.22.0 in /usr/local/lib/python3.10/dist-packages (from matplotlib&gt;=3.5-&gt;SALib) (4.51.0)

Requirement already satisfied: kiwisolver&gt;=1.0.1 in /usr/local/lib/python3.10/dist-packages (from matplotlib&gt;=3.5-&gt;SALib) (1.4.5)

Requirement already satisfied: packaging&gt;=20.0 in /usr/local/lib/python3.10/dist-packages (from matplotlib&gt;=3.5-&gt;SALib) (24.0)

Requirement already satisfied: pillow&gt;=6.2.0 in /usr/local/lib/python3.10/dist-packages (from matplotlib&gt;=3.5-&gt;SALib) (9.4.0)

Requirement already satisfied: pyparsing&gt;=2.3.1 in /usr/local/lib/python3.10/dist-packages (from matplotlib&gt;=3.5-&gt;SALib) (3.1.2)

Requirement already satisfied: python-dateutil&gt;=2.7 in /usr/local/lib/python3.10/dist-packages (from matplotlib&gt;=3.5-&gt;SALib) (2.8.2)

Requirement already satisfied: pytz&gt;=2020.1 in /usr/local/lib/python3.10/dist-packages (from pandas&gt;=2.0-&gt;SALib) (2023.4)

Requirement already satisfied: tzdata&gt;=2022.7 in /usr/local/lib/python3.10/dist-packages (from pandas&gt;=2.0-&gt;SALib) (2024.1)

Requirement already satisfied: dill&gt;0.3.8 in /usr/local/lib/python3.10/dist-packages (from multiprocess-&gt;SALib) (0.3.8)

Requirement already satisfied: six&gt;=1.5 in /usr/local/lib/python3.10/dist-packages (from python-dateutil&gt;=2.7-&gt;matplotlib&gt;=3.5-&gt;SALib) (1.5.2)

Installing collected packages: multiprocess, pandas, SALib

Attempting uninstall: pandas

Found existing installation: pandas 1.5.3

Uninstalling pandas-1.5.3:

Successfully uninstalled pandas-1.5.3

ERROR: pip's dependency resolver does not currently take into account all the packages that are installed. This behaviour is the source of google-colab 1.0.0 requires pandas==2.0.3, but you have pandas 2.2.2 which is incompatible.

interpret-community 0.31.0 requires pandas&lt;2.0.0, but you have pandas 2.2.2 which is incompatible.

ml-wrappers 0.5.5 requires pandas&lt;2.0.0, but you have pandas 2.2.2 which is incompatible.

Successfully installed SALib-1.5.0 multiprocess-0.70.16 pandas-2.2.2

Collecting dice-ml

Downloading dice\_ml-0.11-py3-none-any.whl (2.5 MB)

2.5/2.5 MB 11.1 MB/s eta 0:00:00

Requirement already satisfied: jsonschema in /usr/local/lib/python3.10/dist-packages (from dice-ml) (4.19.2)

Requirement already satisfied: numpy in /usr/local/lib/python3.10/dist-packages (from dice-ml) (1.25.2)

Collecting pandas&lt;2.0.0 (from dice-ml)

Using cached pandas-1.5.3-cp310-cp310-manylinux\_2\_17\_x86\_64.manylinux2014\_x86\_64.whl (12.1 MB)

Requirement already satisfied: scikit-learn in /usr/local/lib/python3.10/dist-packages (from dice-ml) (1.2.2)

Requirement already satisfied: tqdm in /usr/local/lib/python3.10/dist-packages (from dice-ml) (4.66.2)

Requirement already satisfied: raiutils&gt;=0.4.0 in /usr/local/lib/python3.10/dist-packages (from dice-ml) (0.4.2)

Requirement already satisfied: python-dateutil&gt;=2.8.1 in /usr/local/lib/python3.10/dist-packages (from pandas&lt;2.0.0-&gt;dice-ml) (2.8.2)

Requirement already satisfied: pytz&gt;=2020.1 in /usr/local/lib/python3.10/dist-packages (from pandas&lt;2.0.0-&gt;dice-ml) (2023.4)

Requirement already satisfied: requests in /usr/local/lib/python3.10/dist-packages (from raiutils&gt;=0.4.0-&gt;dice-ml) (2.31.0)

Requirement already satisfied: scipy in /usr/local/lib/python3.10/dist-packages (from raiutils&gt;=0.4.0-&gt;dice-ml) (1.11.4)

Requirement already satisfied: attrs&gt;=22.2.0 in /usr/local/lib/python3.10/dist-packages (from jsonschema-&gt;dice-ml) (23.2.0)

Requirement already satisfied: jsonschema-specifications&gt;=2023.03.6 in /usr/local/lib/python3.10/dist-packages (from jsonschema-&gt;dice-ml)

Requirement already satisfied: referencing&gt;=0.28.4 in /usr/local/lib/python3.10/dist-packages (from jsonschema-&gt;dice-ml) (0.35.0)

Requirement already satisfied: rpds-py&gt;=0.7.1 in /usr/local/lib/python3.10/dist-packages (from jsonschema-&gt;dice-ml) (0.18.0)

Requirement already satisfied: joblib&gt;=1.1.1 in /usr/local/lib/python3.10/dist-packages (from scikit-learn-&gt;dice-ml) (1.4.0)

Requirement already satisfied: threadpoolctl&gt;=2.0.0 in /usr/local/lib/python3.10/dist-packages (from scikit-learn-&gt;dice-ml) (3.5.0)

Requirement already satisfied: six&gt;=1.5 in /usr/local/lib/python3.10/dist-packages (from python-dateutil&gt;=2.8.1-&gt;pandas&lt;2.0.0-&gt;dice-ml) (1)

Requirement already satisfied: charset-normalizer&lt;4,&gt;=2 in /usr/local/lib/python3.10/dist-packages (from requests-&gt;raiutils&gt;=0.4.0-&gt;dice-ml)

Requirement already satisfied: idna&lt;4,&gt;=2.5 in /usr/local/lib/python3.10/dist-packages (from requests-&gt;raiutils&gt;=0.4.0-&gt;dice-ml) (3.7)

Requirement already satisfied: urllib3&lt;3,&gt;=2.1.1 in /usr/local/lib/python3.10/dist-packages (from requests-&gt;raiutils&gt;=0.4.0-&gt;dice-ml) (2.1)

Requirement already satisfied: certifi&gt;=2017.4.17 in /usr/local/lib/python3.10/dist-packages (from requests-&gt;raiutils&gt;=0.4.0-&gt;dice-ml) (20.1)

Installing collected packages: pandas, dice-ml

Attempting uninstall: pandas

Found existing installation: pandas 2.2.2

Uninstalling pandas-2.2.2:

Successfully uninstalled pandas-2.2.2

ERROR: pip's dependency resolver does not currently take into account all the packages that are installed. This behaviour is the source of google-colab 1.0.0 requires pandas==2.0.3, but you have pandas 1.5.3 which is incompatible.

salib 1.5.0 requires pandas&gt;=2.0, but you have pandas 1.5.3 which is incompatible.

Successfully installed dice-ml-0.11 pandas-1.5.3

Requirement already satisfied: pip in /usr/local/lib/python3.10/dist-packages (23.1.2)

Collecting install

Downloading install-1.3.5-py3-none-any.whl (3.2 kB)

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COLLECTING SPECTRALCLUSTER
  Downloading spectralcluster-0.2.21-py3-none-any.whl (31 kB)
Installing collected packages: spectralcluster, install
Successfully installed install-1.3.5 spectralcluster-0.2.21
Requirement already satisfied: kaleido in /usr/local/lib/python3.10/dist-packages (0.2.1)
Requirement already satisfied: requests in /usr/local/lib/python3.10/dist-packages (2.31.0)
Requirement already satisfied: charset-normalizer<4,>=2 in /usr/local/lib/python3.10/dist-packages (from requests) (3.3.2)
Requirement already satisfied: idna<4,>=2.5 in /usr/local/lib/python3.10/dist-packages (from requests) (3.7)
Requirement already satisfied: urllib3<3,>=1.21.1 in /usr/local/lib/python3.10/dist-packages (from requests) (2.0.7)
Requirement already satisfied: certifi>=2017.4.17 in /usr/local/lib/python3.10/dist-packages (from requests) (2024.2.2)
Collecting shapash
  Downloading shapash-2.4.3-py2.py3-none-any.whl (651 kB)
                                             651.7/651.7 kB 6.7 MB/s eta 0:00:00
Requirement already satisfied: plotly>=5.0.0 in /usr/local/lib/python3.10/dist-packages (from shapash) (5.15.0)
Requirement already satisfied: matplotlib>=3.2.0 in /usr/local/lib/python3.10/dist-packages (from shapash) (3.7.1)
Requirement already satisfied: numpy>=1.18.0 in /usr/local/lib/python3.10/dist-packages (from shapash) (1.25.2)
Requirement already satisfied: pandas>=1.0.2 in /usr/local/lib/python3.10/dist-packages (from shapash) (1.5.3)
Requirement already satisfied: shap<0.45.0,>=0.38.1 in /usr/local/lib/python3.10/dist-packages (from shapash) (0.44.0)
Requirement already satisfied: Flask<2.3.0 in /usr/local/lib/python3.10/dist-packages (from shapash) (2.2.5)
Collecting dash>=2.3.1 (from shapash)
  Downloading dash-2.16.1-py3-none-any.whl (10.2 kB)
                                             10.2/10.2 kB 23.5 MB/s eta 0:00:00
Collecting dash-bootstrap-components>=1.1.0 (from shapash)
  Downloading dash_bootstrap_components-1.6.0-py3-none-any.whl (222 kB)
                                             222.5/222.5 kB 22.2 MB/s eta 0:00:00
Collecting dash-core-components>=2.0.0 (from shapash)
  Downloading dash_core_components-2.0.0-py3-none-any.whl (3.8 kB)
Collecting dash-daq>=0.5.0 (from shapash)
  Downloading dash_daq-0.5.0.tar.gz (642 kB)
                                             642.7/642.7 kB 29.7 MB/s eta 0:00:00
Preparing metadata (setup.py) ... done
Collecting dash-html-components>=2.0.0 (from shapash)
  Downloading dash_html_components-2.0.0-py3-none-any.whl (4.1 kB)
Collecting dash-renderer==1.8.3 (from shapash)
  Downloading dash_renderer-1.8.3.tar.gz (1.0 MB)
                                             1.0/1.0 kB 35.2 MB/s eta 0:00:00
Preparing metadata (setup.py) ... done
Collecting dash-table>=5.0.0 (from shapash)
  Downloading dash_table-5.0.0-py3-none-any.whl (3.9 kB)
Requirement already satisfied: nbformat>4.2.0 in /usr/local/lib/python3.10/dist-packages (from shapash) (5.10.4)
Requirement already satisfied: numba>=0.53.1 in /usr/local/lib/python3.10/dist-packages (from shapash) (0.58.1)
Requirement already satisfied: scikit-learn<1.4,>=1.0.1 in /usr/local/lib/python3.10/dist-packages (from shapash) (1.2.2)
Collecting category-encoders>=2.6.0 (from shapash)
  Downloading category_encoders-2.6.3-py2.py3-none-any.whl (81 kB)
                                             81.9/81.9 kB 9.0 MB/s eta 0:00:00
Requirement already satisfied: scipy>=0.19.1 in /usr/local/lib/python3.10/dist-packages (from shapash) (1.11.4)
Requirement already satisfied: statsmodels>=0.9.0 in /usr/local/lib/python3.10/dist-packages (from category-encoders>=2.6.0->shapash) (0.1)
Requirement already satisfied: patsy>=0.5.1 in /usr/local/lib/python3.10/dist-packages (from category-encoders>=2.6.0->shapash) (0.5.6)
Requirement already satisfied: Werkzeug<3.1 in /usr/local/lib/python3.10/dist-packages (from dash>=2.3.1->shapash) (3.0.2)
Requirement already satisfied: importlib-metadata in /usr/local/lib/python3.10/dist-packages (from dash>=2.3.1->shapash) (7.1.0)
Requirement already satisfied: typing-extensions>=4.1.1 in /usr/local/lib/python3.10/dist-packages (from dash>=2.3.1->shapash) (4.11.0)
Requirement already satisfied: requests in /usr/local/lib/python3.10/dist-packages (from dash>=2.3.1->shapash) (2.31.0)
Collecting retrying (from dash>=2.3.1->shapash)
  Downloading retrying-1.3.4-py3-none-any.whl (11 kB)
Requirement already satisfied: nest-asyncio in /usr/local/lib/python3.10/dist-packages (from dash>=2.3.1->shapash) (1.6.0)
Requirement already satisfied: setuptools in /usr/local/lib/python3.10/dist-packages (from dash>=2.3.1->shapash) (67.7.2)
Requirement already satisfied: Jinja2>=3.0 in /usr/local/lib/python3.10/dist-packages (from Flask>2.3.0->shapash) (3.1.3)
Requirement already satisfied: itsdangerous>=2.0 in /usr/local/lib/python3.10/dist-packages (from Flask>2.3.0->shapash) (2.2.0)
Requirement already satisfied: click>=8.0 in /usr/local/lib/python3.10/dist-packages (from Flask>2.3.0->shapash) (8.1.7)
Requirement already satisfied: contourpy>=1.0.1 in /usr/local/lib/python3.10/dist-packages (from matplotlib>=3.2.0->shapash) (1.2.1)
Requirement already satisfied: cycler>=0.10 in /usr/local/lib/python3.10/dist-packages (from matplotlib>=3.2.0->shapash) (0.12.1)
Requirement already satisfied: fonttools>=4.22.0 in /usr/local/lib/python3.10/dist-packages (from matplotlib>=3.2.0->shapash) (4.51.0)
Requirement already satisfied: kiwisolver>=1.0.1 in /usr/local/lib/python3.10/dist-packages (from matplotlib>=3.2.0->shapash) (1.4.5)
Requirement already satisfied: packaging>=20.0 in /usr/local/lib/python3.10/dist-packages (from matplotlib>=3.2.0->shapash) (24.0)
Requirement already satisfied: pillow>=6.2.0 in /usr/local/lib/python3.10/dist-packages (from matplotlib>=3.2.0->shapash) (9.4.0)
Requirement already satisfied: pyparsing>=2.3.1 in /usr/local/lib/python3.10/dist-packages (from matplotlib>=3.2.0->shapash) (3.1.2)
Requirement already satisfied: python-dateutil>=2.7 in /usr/local/lib/python3.10/dist-packages (from matplotlib>=3.2.0->shapash) (2.8.2)
Requirement already satisfied: fastjsonschema>=2.15 in /usr/local/lib/python3.10/dist-packages (from nbformat>4.2.0->shapash) (2.19.1)
Requirement already satisfied: jsonschema>=2.6.0 in /usr/local/lib/python3.10/dist-packages (from nbformat>4.2.0->shapash) (4.19.2)
Requirement already satisfied: jupyter-core!=5.0.*,>=4.12 in /usr/local/lib/python3.10/dist-packages (from nbformat>4.2.0->shapash) (5.7.2)
Requirement already satisfied: traitlets>=5. in /usr/local/lib/python3.10/dist-packages (from nbformat>4.2.0->shapash) (5.7.1)
Requirement already satisfied: llvmlite<0.42,>=0.41.0dev0 in /usr/local/lib/python3.10/dist-packages (from numba>=0.53.1->shapash) (0.41.1)
Requirement already satisfied: pytz>=2020.1 in /usr/local/lib/python3.10/dist-packages (from pandas>1.0.2->shapash) (2023.4)
Requirement already satisfied: tenacity>=6.2.0 in /usr/local/lib/python3.10/dist-packages (from plotly>=5.0.0->shapash) (8.2.3)
Requirement already satisfied: joblib>=1.1.1 in /usr/local/lib/python3.10/dist-packages (from scikit-learn<1.4,>=1.0.1->shapash) (1.4.0)
Requirement already satisfied: threadpoolctl>=2.0.0 in /usr/local/lib/python3.10/dist-packages (from scikit-learn<1.4,>=1.0.1->shapash) (3)
Requirement already satisfied: tqdm>=4.27.0 in /usr/local/lib/python3.10/dist-packages (from shap<0.45.0,>=0.38.1->shapash) (4.66.2)
Requirement already satisfied: slicer>=0.7 in /usr/local/lib/python3.10/dist-packages (from shap<0.45.0,>=0.38.1->shapash) (0.0.7)
Requirement already satisfied: cloudpickle in /usr/local/lib/python3.10/dist-packages (from shap<0.45.0,>=0.38.1->shapash) (2.2.1)
Requirement already satisfied: MarkupSafe>=2.0 in /usr/local/lib/python3.10/dist-packages (from Jinja2>=3.0->Flask>2.3.0->shapash) (2.1.5)
Requirement already satisfied: attrs>=22.2.0 in /usr/local/lib/python3.10/dist-packages (from jsonschema>=2.6->nbformat>4.2.0->shapash) (2)
Requirement already satisfied: jsonschema-specifications>=2023.03.6 in /usr/local/lib/python3.10/dist-packages (from jsonschema>=2.6->nbfo)
Requirement already satisfied: referencing>=0.28.4 in /usr/local/lib/python3.10/dist-packages (from jsonschema>=2.6->nbformat>4.2.0->shapash)
Requirement already satisfied: rpdbs-py>=0.7.1 in /usr/local/lib/python3.10/dist-packages (from jsonschema>=2.6->nbformat>4.2.0->shapash) (1)
Requirement already satisfied: platformdirs>=2.5 in /usr/local/lib/python3.10/dist-packages (from jupyter-core!=5.0.*,>=4.12->nbformat>4.2)
Requirement already satisfied: six in /usr/local/lib/python3.10/dist-packages (from patsy>=0.5.1->category-encoders>=2.6.0->shapash) (1.16)
Requirement already satisfied: zipp>=0.5 in /usr/local/lib/python3.10/dist-packages (from importlib-metadata>dash>=2.3.1->shapash) (3.18)
Requirement already satisfied: charset-normalizer<4,>=2 in /usr/local/lib/python3.10/dist-packages (from requests>dash>=2.3.1->shapash) (1)
Requirement already satisfied: idna<4,>=2.5 in /usr/local/lib/python3.10/dist-packages (from requests>dash>=2.3.1->shapash) (3.7)
Requirement already satisfied: urllib3<3,>=1.21.1 in /usr/local/lib/python3.10/dist-packages (from requests>dash>=2.3.1->shapash) (2.0.7)
Requirement already satisfied: certifi>=2017.4.17 in /usr/local/lib/python3.10/dist-packages (from requests>dash>=2.3.1->shapash) (2024.2)
Building wheels for collected packages: dash-renderer, dash-daq
  Building wheel for dash-renderer (setup.py) ... done
  Created wheel for dash-renderer: filename=dash_renderer-1.8.3-py3-none-any.whl size=1013921 sha256=d14de03d2e853e07e0c8cc2ac13b54c02e36d
  Stored in directory: /root/.cache/nin/wheels/6f/0d/c8/72a0h5a276c3erh61a17a27rd4hhe7fad32d1417hhhdh4d46aef

```

```

  ... in directory: /root/.cache/pip/wheels/0c/07/c0/22d0032e2c3117a2/47dcf1002e1717d0000000000000000
Building wheel for dash-daq (setup.py) ... done
Created wheel for dash-daq: filename=dash_daq-0.5.0-py3-none-any.whl size=669692 sha256=701034d17367f2517d31eed17188e13bd2f00d2b1a3c0231
Stored in directory: /root/.cache/pip/wheels/75/14/1b/208d09d5e239391048bcd167759977b41ba65a3d4063aebf6b
Successfully built dash-renderer dash-daq
Installing collected packages: dash-table, dash-renderer, dash-html-components, dash-core-components, retrying, dash, dash-daq, dash-boots...
Successfully installed category-encoders-2.6.3 dash-2.16.1 dash-bootstrap-components-1.6.0 dash-core-components-2.0.0 dash-daq-0.5.0 dash-l

# download files and models
import gdown
import pickle
import requests

# Basic data handling and scientific computing
import numpy as np # Numerical computing library
import pandas as pd # Data manipulation and analysis
import random
from numpy import arange

# Visualization libraries
import seaborn as sns # Statistical data visualization
import matplotlib.pyplot as plt # Basic plotting library
import plotly.express as px # Interactive plotting library
import plotly.graph_objects as go # For creating custom plots with Plotly
from plotly.subplots import make_subplots # For creating subplots with Plotly

# Data preprocessing and model evaluation tools
from sklearn.impute import SimpleImputer # For handling missing data
from sklearn.model_selection import StratifiedShuffleSplit # For creating stratified splits
from sklearn.preprocessing import RobustScaler, StandardScaler # Data scaling methods
from sklearn.decomposition import PCA # Principal Component Analysis
from sklearn.pipeline import Pipeline # For creating modeling pipelines
from sklearn.metrics import accuracy_score, confusion_matrix # Model evaluation metrics
from sklearn.metrics import precision_recall_fscore_support # Precision, recall, and F1 score
from sklearn.metrics import roc_auc_score # AUC score

# Machine learning models
from sklearn.linear_model import LogisticRegression # Logistic regression model
from sklearn.ensemble import RandomForestClassifier, VotingClassifier # Ensemble models
from sklearn.neighbors import KNeighborsClassifier # k-Nearest Neighbors model
from sklearn.svm import SVC # Support Vector Machine model
from sklearn.neural_network import MLPClassifier

# Model selection and hyperparameter tuning
from sklearn.model_selection import GridSearchCV # For hyperparameter tuning

# Data balancing techniques
from imblearn.over_sampling import SMOTE, ADASYN # Over-sampling techniques
from imblearn.over_sampling import RandomOverSampler # Random over-sampling

# Additional utilities
from typing import List # For type hints
from google.colab import drive # Google Colab drive integration (if using Google Colab)
import warnings # For controlling warning messages
warnings.filterwarnings('ignore') # Suppress warning messages for cleaner output
# Plotly setup for notebooks
from plotly.offline import plot, iplot, init_notebook_mode
# init_notebook_mode(connected=True)

# Local explainability
from sklearn.inspection import permutation_importance
from sklearn.inspection import PartialDependenceDisplay, partial_dependence
from interpret_community.mimic.mimic_explainer import MimicExplainer
from interpret_community.mimic.models import LinearExplainableModel
from interpret.blackbox import MorrisSensitivity
import shap
import lime
from lime import lime_tabular
from treeinterpreter import treeinterpreter as ti

```

Checkpoint: Project Files

```

gdown.download(id='11swC5N9lqEVTp3E-K1dtBrlHQEoEkxtk', output="project_files.tgz")
!tar -xzf project_files.tgz

```

```
root = 'DL4H_Sp24_Final_Project'
```

## ▼ Data

The raw dataset comes and can be downloaded from from UC Irvine Machine Learning Repository

<https://archive.ics.uci.edu/dataset/383/cervical+cancer+risk+factors>

Fernandes,Kelwin, Cardoso,Jaime, and Fernandes,Jessica. (2017). Cervical Cancer (Risk Factors). UCI Machine Learning Repository.

<https://doi.org/10.24432/C5Z310>

The dataset was collected at 'Hospital Universitario de Caracas' in Caracas, Venezuela. The dataset contains demographic information, habits, and historic medical records of 858 patients. Several patients decided not to answer some of the questions because of privacy concerns (missing values represented as '?').

The missing values certainly make some of the columns less accurate. Time since STD Diagnosis is largely unknown, followed by presence of an IUD. So there is not a perfect correlation to be determined for every feature.

We load the raw data, place it in our project directory, and display statistics, showing how many patients are without cancer and with cancer. We display the number of unknowns before we clean our data.

To clean and process the data, we convert numerical 'object' columns to integers. We replace '?'s with the median of that column. We rerun the overall statistics to confirm there are no "unknown" values and the number of cancer patients remained the same. We create a new age\_category column that stratifies the ages.

We run statistics on the age category to gain context. For example, we can see things like just over 2% of the dataset is diagnosed with cancer, but 44% of those diagnosed with cancer are in their 30's, and 20% of patients who are in their 50's have cancer. (We must remember the dataset is small, which is why we sample using ADASYN). There are only 4 patients 70 or older, and they all happen to not have cancer. This does not mean age is not important.

#### ▼ Processing and Statistics

✓ Checkpoint: Load Data Function

```
def load_data(data_dir):
    # implement this function to load raw data to dataframe/numpy array/tensor
    return pd.read_csv(data_dir, delimiter=',', encoding='utf-8')
```

✓ Checkpoint: Load Raw Data

```
root = '/content/drive/My Drive/DL4H_Sp24_Final_Project/'
# dir and function to load raw data
have_access = True

try:
    data_dir = '/content/drive/My Drive/DL4H_Sp24_Final_Project/risk_factors_cervical_cancer.csv'
    raw_risk_factor_df = load_data(data_dir)
    have_access = True
except:
    have_access = False
    data_dir = 'risk_factors_cervical_cancer.csv'
    # gdown.download('https://drive.google.com/file/d/13Co6aIxBU4KXMH56TDyQd70pkk_b4l2/view?usp=sharing', data_dir, format='csv', fuzzy=True, quiet=True)
    raw_risk_factor_df = load_data('DL4H_Sp24_Final_Project/risk_factors_cervical_cancer.csv')
    print("No access, Used Gdown!")
# https://drive.google.com/drive/folders/1AUr8BgW16UU-7XjFF8077XAgjA27gISV?usp=sharing
raw_risk_factor_df
```

No access, Used Gdown!

Age	Number of sexual partners	First sexual intercourse	Num of pregnancies	Smokes	Smokes (years)	Smokes (packs/year)	Hormonal Contraceptives	Hormonal Contraceptives (years)	IUD	...	STDs: Time since first diagnosis		STDs: Time since last diagnosis	
											diagnosis	diagnosis	D	
0	18	4.0	15.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	...	?	?	
1	15	1.0	14.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	...	?	?
2	34	1.0	?	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	...	?	?
3	52	5.0	16.0	4.0	1.0	37.0	37.0	1.0	3.0	0.0	...	?	?	
4	46	3.0	21.0	4.0	0.0	0.0	0.0	1.0	15.0	0.0	...	?	?	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	
853	34	3.0	18.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	...	?	?
854	32	2.0	19.0	1.0	0.0	0.0	0.0	1.0	8.0	0.0	...	?	?	
855	25	2.0	17.0	0.0	0.0	0.0	0.0	1.0	0.08	0.0	...	?	?	
856	33	2.0	24.0	2.0	0.0	0.0	0.0	1.0	0.08	0.0	...	?	?	
857	29	20	20.0	1.0	0.0	0.0	0.0	1.0	0.5	0.0	...	?	?	

✓ Checkpoint: Define Statistics methods

```
# calculate dataset statistics
def calculate_dataset_stats(df):
    print(len(df), " total patients")
    print(df['Dx:Cancer'].value_counts()[0], " patients without Cancer")
    print(df['Dx:Cancer'].value_counts()[1], " patients with Cancer")
    print(df.applymap(lambda x: x == "?").sum().sum(), " unknown values")
    specified_value = '?' # Replace with the value you're interested in
    max_count = -1
    column_with_most = None

    for column in df.columns:
        if column == "STDs: Time since last diagnosis" or column == "STDs: Time since first diagnosis":
            continue
        value_counts = df[column].value_counts()
        if specified_value in value_counts:
            if value_counts[specified_value] > max_count:
                max_count = value_counts[specified_value]
                column_with_most = column

    print(f"Column with the most '{specified_value}': {column_with_most} (Count: {max_count})")
    dataset_size = df.shape[0] * df.shape[1]
    print(100 * df.applymap(lambda x: x == "?").sum().sum() / dataset_size, " percent of the dataset is unknown")

    # Formatting to match the style: dtypes: float64(2), int64(2), object(1)
    formatted_summary = ", ".join([f"{k}: {v}" for k, v in df.dtypes.value_counts().items()])
    print("dtypes:", formatted_summary)
```

```
# NOTE: this is a deviation from the source code. In the source code, category_percent
# summed up to 100 across the diagnosis, we also wanted to show the percent for each category

def col_stats(df, diagnosis_column, category_column):
    """
    Calculates statistics for diagnosis distributions across categories.

    Parameters:
    - df (DataFrame): The input data frame containing the relevant data.
    - diagnosis_column (str): The name of the column containing diagnosis information.
    - category_column (str): The name of the column containing category labels (e.g., age groups).

    Returns:
    - DataFrame: A pivot table presenting the calculated statistics.
    """

    # Calculate the overall percentage of each diagnosis-category combination.
    overall_percentages = df[[diagnosis_column, category_column]] \
        .value_counts(normalize=True) \
        .mul(100) \
        .round(decimals=4) \
        .reset_index(name='Overall_Percent')

    # Count the occurrences within each category for a diagnosis.
    diagnosis_by_category_counts = df.groupby([diagnosis_column, category_column]) \
        .size() \
        .reset_index(name='Count_in_Category')

    # Count the total occurrences within each category.
    total_in_category = df.groupby(category_column) \
        .size() \
        .reset_index(name='Total_in_Category')

    # Calculate the percentage of each diagnosis within specific categories.
    category_percentages = pd.merge(diagnosis_by_category_counts, total_in_category, on=category_column)
    category_percentages['Category_Percent'] = category_percentages['Count_in_Category'] \
        .div(category_percentages['Total_in_Category']) \
        .mul(100) \
        .round(decimals=4)

    # Count occurrences of each diagnosis and calculate the percentage within the diagnosis.
    diagnosis_counts_and_percentages = pd.merge(
        df.groupby([diagnosis_column, category_column]).size().reset_index(name='Individual_Count'),
        df.groupby(diagnosis_column).size().reset_index(name='Total_in_Diagnosis'),
        on=diagnosis_column
    )
    diagnosis_counts_and_percentages['Diagnosis_Percent'] = diagnosis_counts_and_percentages['Individual_Count'] \
        .div(diagnosis_counts_and_percentages['Total_in_Diagnosis']) \
        .mul(100) \
        .round(4)

    # Merge the overall percentages with category-specific percentages.
    temp_merged = pd.merge(
        overall_percentages,
        category_percentages[[diagnosis_column, category_column, 'Category_Percent']],
        on=[diagnosis_column, category_column]
    )

    # Merge with the diagnosis percentage data.
    final_merged = pd.merge(
        temp_merged,
        diagnosis_counts_and_percentages[[diagnosis_column, category_column, 'Diagnosis_Percent']],
        on=[diagnosis_column, category_column]
    )

    # Create a pivot table for better presentation.
    final_pivot_table = final_merged.pivot(index=category_column, columns=diagnosis_column).reset_index()
    final_pivot_table.fillna(0.000, inplace=True)
    return final_pivot_table

def print_unique_values_df(df: pd.DataFrame):
    for col in list(df):
        print("Number of Unique Values for '{}': {}".format(str(col), len(risk_factor_df[col].unique())))
        print("dtype for {} is {}".format(str(col), risk_factor_df[col].dtypes))
        print("-" * 150)
```

✓ Checkpoint: Define Processing Method

```

# process raw data
def process_data(raw_data):
    # implement this function to process the data as you need
    #these columns are not of type object, but are of type numeric
    cols_to_convert = ['Number of sexual partners', 'First sexual intercourse', 'Num of pregnancies', 'Smokes',
                       'Smokes (years)', 'Smokes (packs/year)', 'Hormonal Contraceptives',
                       'Hormonal Contraceptives (years)', 'IUD', 'IUD (years)', 'STDs', 'STDs (number)',
                       'STDs:condylomatosis', 'STDs:cervical condylomatosis', 'STDs:vaginal condylomatosis',
                       'STDs:vulvo-perineal condylomatosis', 'STDs:syphilis', 'STDs:pelvic inflammatory disease',
                       'STDs:genital herpes', 'STDs:molluscum contagiosum', 'STDs:AIDS', 'STDs:HIV', 'STDs:Hepatitis B',
                       'STDs:HPV', 'STDs: Time since first diagnosis',
                       'STDs: Time since last diagnosis']

    std_cols = {'STDs:condylomatosis',
                'STDs:cervical condylomatosis',
                'STDs:vaginal condylomatosis',
                'STDs:vulvo-perineal condylomatosis',
                'STDs:syphilis',
                'STDs:pelvic inflammatory disease',
                'STDs:genital herpes',
                'STDs:molluscum contagiosum',
                'STDs:AIDS',
                'STDs:HIV',
                'STDs:Hepatitis B',
                'STDs:HPV'}

    test_cols = ["Hinselmann", "Schiller", "Citology", "Biopsy"]

    to_int_and_beyond = {"total_tests",
                         "total_std",
                         "Smokes",
                         "Biopsy",
                         "Dx:Cancer",
                         "Num of pregnancies",
                         "Number of sexual partners",
                         "First sexual intercourse",
                         "Hormonal Contraceptives",
                         "IUD",
                         "STDs",
                         "STDs (number)",
                         "STDs: Number of diagnosis",
                         "Dx:CIN",
                         "Dx:HPV",
                         "Dx",
                         "Hinselmann",
                         "Schiller",
                         "Biopsy",
                         "Citology"}

    to_int_and_beyond = to_int_and_beyond.union(std_cols)

    # convert object columns to numeric and replace with nan
    raw_data[cols_to_convert] = raw_data[cols_to_convert].apply(pd.to_numeric, errors="coerce")
    raw_data[cols_to_convert].fillna(np.nan, inplace=True)
    # replace nan values with the median of the column
    imp = SimpleImputer(strategy="median")
    X = imp.fit_transform(raw_data)
    risk_factor_df = pd.DataFrame(X, columns=list(raw_data.columns))

    # make new columns
    risk_factor_df["Age"] = risk_factor_df["Age"].astype(int)
    risk_factor_df["age_cat"] = risk_factor_df["Age"].apply(age_cat)
    risk_factor_df["total_std"] = risk_factor_df[list(std_cols)].sum(axis=1)
    risk_factor_df["total_tests"] = risk_factor_df[test_cols].sum(axis = 1)
    for col in to_int_and_beyond:
        risk_factor_df[col] = risk_factor_df[col].astype(int)

    # Aggregate the STD counts by age categories
    std_agg = risk_factor_df.groupby("age_cat", as_index=False)[list(std_cols)].sum()
    return risk_factor_df, std_agg

# categorize the age ranges
def age_cat(age):
    if age < 12:
        return "Child"
    elif age < 20:
        return "Teen"
    elif age < 30:
        return "20's"
    elif age < 40:
        return "30's"
    elif age < 50:
        return "40's"
    elif age < 60:
        return "50's"
    elif age < 70:
        return "60's"

```

```

        return "60's"
    else:
        return "70+"

def save_data(df, path):
    if have_access:
        print("Save checkpoint granted")
        df.to_csv(path, index=False)
    else:
        print("You have no access to save data, skipping save checkpoint")

```

#### ✓ Checkpoint: Calculate Raw Data Stats

```

print('RAW DATA STATS')
calculate_dataset_stats(raw_risk_factor_df)

RAW DATA STATS
858 total patients
840 patients without Cancer
18 patients with Cancer
3622 unknown values
Column with the most '?': IUD (Count: 117)
11.726236726236726 percent of the dataset is unknown
dtypes: object: 26, int64: 10

```

#### ✓ (BEFORE ADASYN) Process Data, Calculate Processed Stats, and Save Data

```

# process data set
risk_factor_df, std_agg = process_data(raw_risk_factor_df)
save_data(risk_factor_df, '/content/drive/My Drive/DL4H_Sp24_Final_Project/processed_risk_factors_cervical_cancer.csv')
save_data(std_agg, '/content/drive/My Drive/DL4H_Sp24_Final_Project/processed_std_agg.csv')

```

```

Save checkpoint granted
Save checkpoint granted

```

#### ✓ Checkpoint: Load Processed Data

```

root
'DL4H_Sp24_Final_Project'

try:
    data_dir = '/content/drive/My Drive/DL4H_Sp24_Final_Project/processed_risk_factors_cervical_cancer.csv'
    risk_factor_df = load_data(data_dir)
    unbalanced_risk_factor_df = risk_factor_df
    data_dir = '/content/drive/My Drive/DL4H_Sp24_Final_Project/processed_std_agg.csv'
    std_agg = load_data(data_dir)
    have_access = True
except:
    have_access = False
    data_dir = root+'/processed_risk_factors_cervical_cancer.csv'
    # gdown.download('https://drive.google.com/file/d/1n-II-zTy0pjToewmetQFrBZ4YKFjfZQU/view?usp=share_link', data_dir, format='csv', fuzzy=True
    risk_factor_df = load_data(data_dir)
    unbalanced_risk_factor_df = risk_factor_df
    data_dir = root+'/processed_std_agg.csv'
    # gdown.download('https://drive.google.com/file/d/110iEdMjfYzcMtZh1jIWQJlI0w4iEbhG/view?usp=share_link', data_dir, format='csv', fuzzy=True
    std_agg = load_data(data_dir)
    print("No access, Used Gdown!")
    print("-" * 150)
    print('PROCESSED DATA STATS')
    # print overall stats, might need to edit
    calculate_dataset_stats(risk_factor_df)
    print("-" * 150)
    # print column specific stats
    print('Dx:Cancer by age category')
    dxCancerByAge = col_stats(risk_factor_df, 'Dx:Cancer', 'age_cat')
    print(dxCancerByAge)

    No access, Used Gdown!
-----
PROCESSED DATA STATS
858 total patients
840 patients without Cancer
18 patients with Cancer
0 unknown values
Column with the most '?': None (Count: -1)
0.0 percent of the dataset is unknown
dtypes: int64: 32, float64: 6, object: 1
-----
```

Dx:Cancer by age category		Category_Percent			
Dx:Cancer	age_cat	Overall_Percent		0	1
0	20's	45.3380	0.5828	98.7310	1.2690 \
1	30's	24.7086	0.9324	96.3636	3.6364
2	40's	6.1772	0.3497	94.6429	5.3571
3	50's	0.4662	0.1166	80.0000	20.0000
4	70+	0.4662	0.0000	100.0000	0.0000
5	Teen	20.7459	0.1166	99.4413	0.5587

Diagnosis_Percent					
Dx:Cancer		0	1		
0		46.3095	27.7778		
1		25.2381	44.4444		
2		6.3095	16.6667		
3		0.4762	5.5556		
4		0.4762	0.0000		
5		21.1905	5.5556		

## ✓ Checkpoint: Visualizations

### ✓ Top features that correlate with cancer Dx

```
# Features that correlate with a cancer diagnosis
n = 7
target = label = "Dx:Cancer"
# correlate the numerical columns of the df
corr = risk_factor_df.select_dtypes(include=np.number).corr()
# find the top 7 correlations with Dx:Cancer
x = corr.nlargest(n,target).index
print(x)
# make a corr_df with only the top 7 columns
corr_df = risk_factor_df[list(x)]
# recalculate the correlation
corr = corr_df.corr()
# Creating a mask for the upper triangle
mask = np.triu(np.ones_like(corr, dtype=bool), k=1)

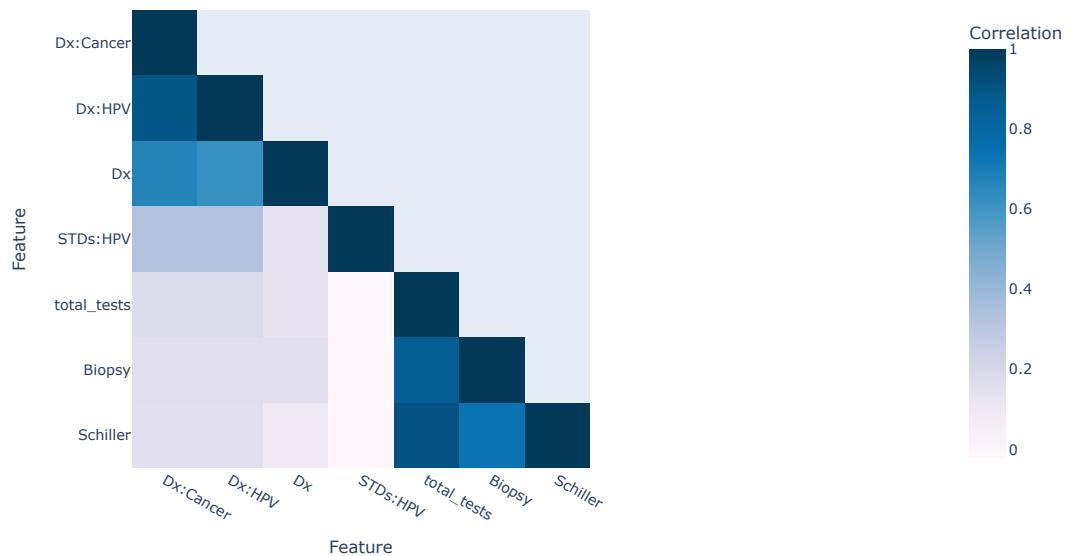
# Use the mask to replace the upper triangle with np.nan
corr_masked = corr.where(~mask)

# Plot using Plotly Express
fig = px.imshow(corr_masked,
                 color_continuous_scale="PuBu",
                 labels=dict(x="Feature", y="Feature", color="Correlation"),
                 x=corr.columns, # Adding column names here
                 y=corr.index) # Adding row names here

# Update layout with title
fig.update_layout(title="Top "+str(n)+" Features Correlated With "+str(target).capitalize())
fig.update_xaxes(showgrid=False)
fig.update_yaxes(showgrid=False)
# Show plot
fig.show()
```

```
Index(['Dx:Cancer', 'Dx:HPV', 'Dx', 'STDs:HPV', 'total_tests', 'Biopsy',
       'Schiller'],
      dtype='object')
```

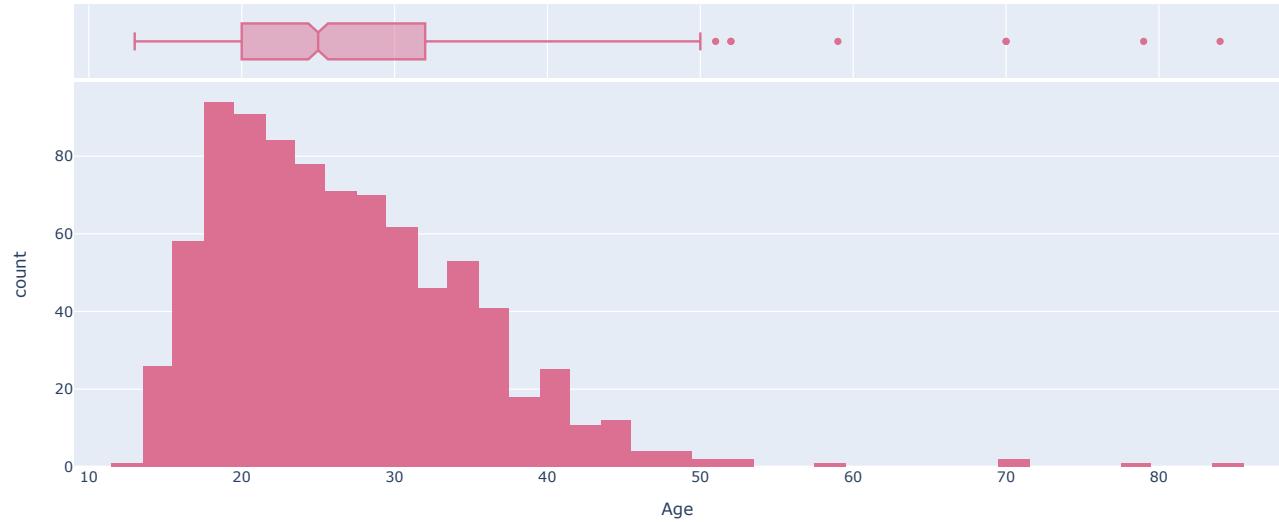
### Top 7 Features Correlated With Dx:cancer



### ▼ Distribution of age

```
# Distribution of age
age_dist = px.histogram(risk_factor_df, x="Age", marginal="box", color_discrete_sequence=["palevioletred"])
age_dist.update_layout(title="Age distribution")
age_dist.show()
```

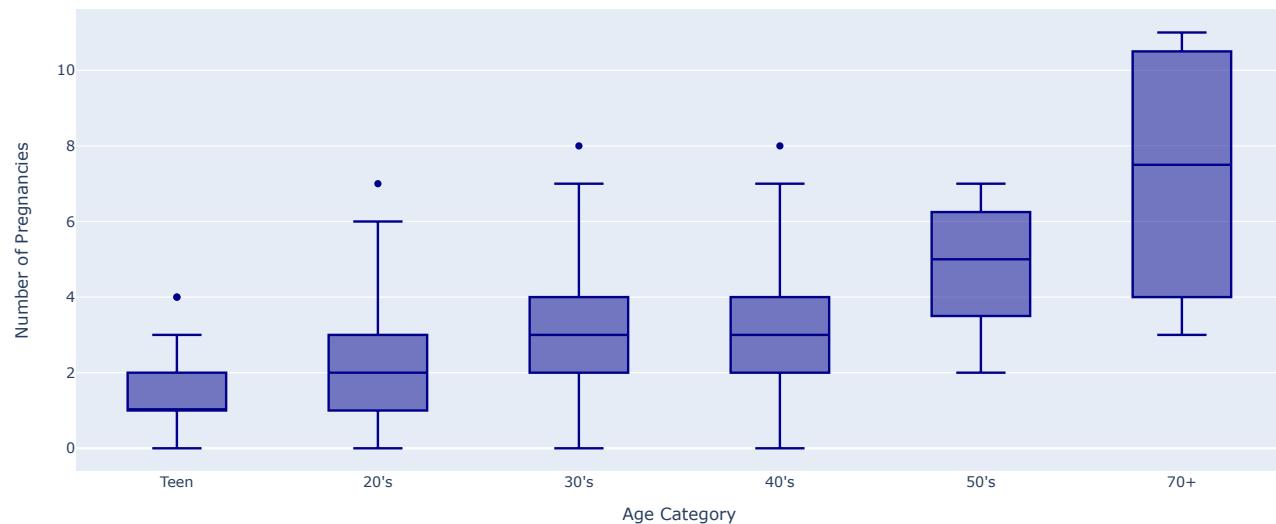
Age distribution



### ▼ Pregnancy Distribution by Age

```
#Pregnancy Distribution by Age
age_preg_bar = px.box(risk_factor_df.sort_values(by="Age", ascending=True), x="age_cat", y="Num of pregnancies",
                      color_discrete_sequence=["darkblue"], points="outliers",
                      category_orders={"Teenager", "Twenties", "Thirties", "Forties", "Fifties", "Sixties",
                                      "Seventy and over"})
age_preg_bar.update_xaxes(title="Age Category")
age_preg_bar.update_yaxes(title="Number of Pregnancies")
age_preg_bar.update_layout(title="Distribution of number of pregnancies per age group")
age_preg_bar.show()
```

### Distribution of number of pregnancies per age group



### Mayo Risk Factors (May split further)

Mayo Clinic provides many risk factors for cervical cancer, including many sexual partners, earlier sexual activity, STIs, a weakened immune system, smoking, and the exposure to miscarriage preventian drug DES.

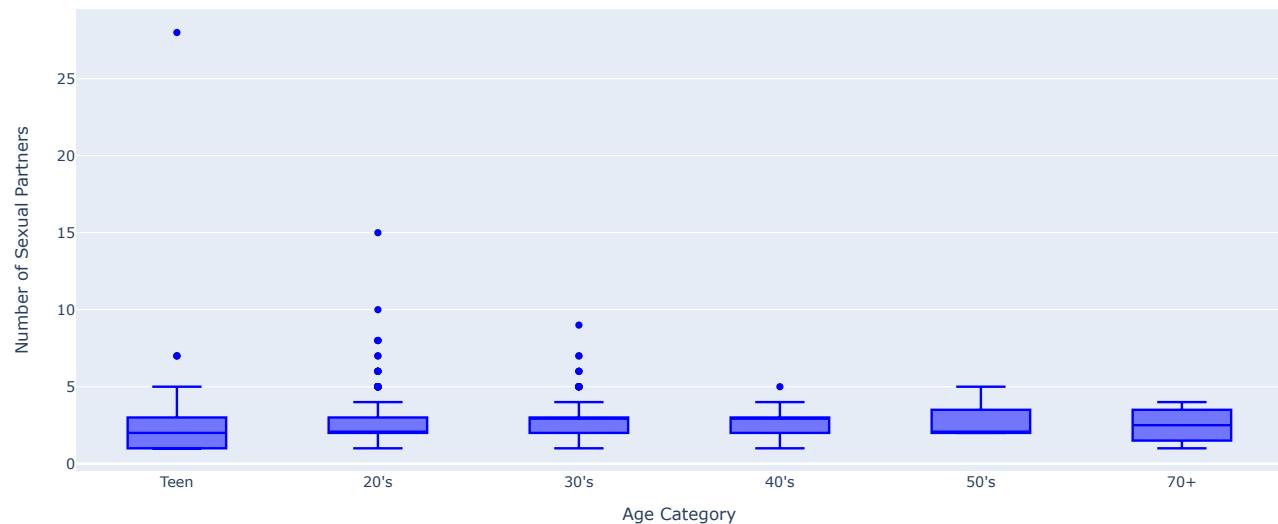
We can see from the following visualizations that number of sexual partners remain fairly consistent across age ranges. We can also see a very low correlation between number of sexual partners and any relevant diagnoses.

We see a very high correlation between HPV and Cancer, but a low correlation between CIN and HPV. This could be due to the incompleteness of this dataset, that we will try to balance alter.

```
# Mayo Risk factors – sexual partners, sexual activity, STIs, immune system, smoking, exposure to drugs

label = 'age_cat'
# Plotting a box plot to visualize the distribution of the number of sexual partners across different age groups.
# The data is sorted by age and plotted with outliers, using a blue color for the data points.
age_num_sex_partners = px.box(risk_factor_df.sort_values(by="Age", ascending=True), x="age_cat", y="Number of sexual partners",
                               color_discrete_sequence=["blue"], points="outliers",
                               category_orders=["Teenager", "Twenties", "Thirties", "Forties", "Fifties",
                                                 "Seventy and over"])
# Updating axis titles for better readability and clarity.
age_num_sex_partners.update_xaxes(title="Age Category")
age_num_sex_partners.update_yaxes(title="Number of Sexual Partners")
# Updating the layout to add a title to the plot.
age_num_sex_partners.update_layout(title="Distribution of number of sexual partners per age group")
# Displaying the plot.
age_num_sex_partners.show()
```

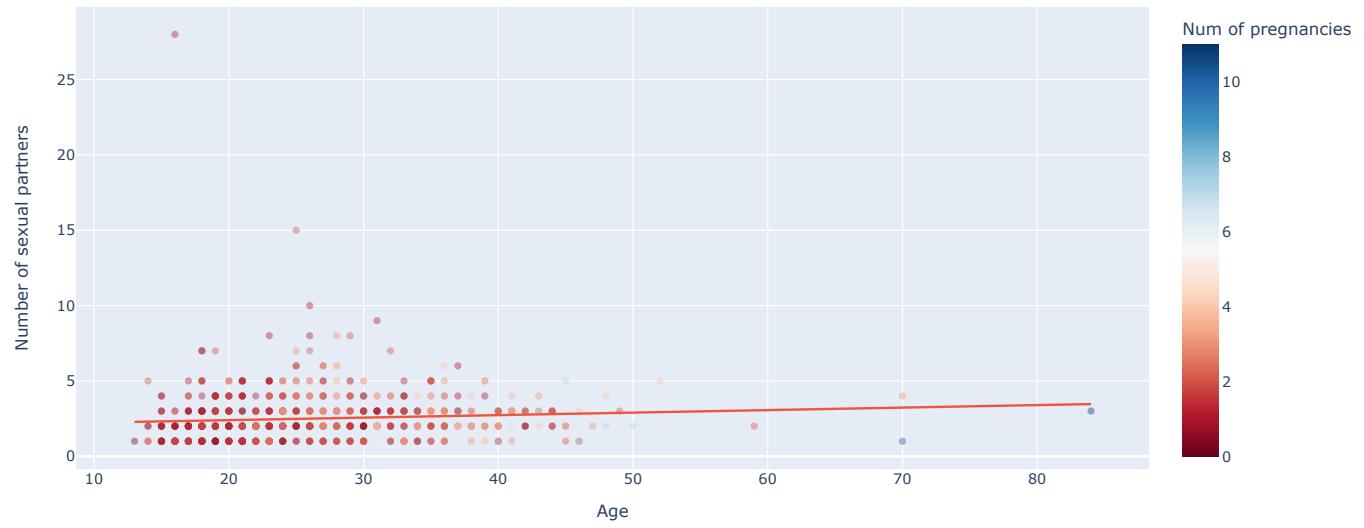
## Distribution of number of sexual partners per age group



```
# Creating a scatter plot to visualize the relationship between age and number of sexual partners.
# The plot includes a trend line (ordinary least squares - OLS) to indicate the general trend.
# Opacity is set to 0.4 to handle overplotting, and color represents the number of pregnancies.
age_num_sex_partners = px.scatter(risk_factor_df, x="Age",
                                   y="Number of sexual partners",
                                   trendline="ols",
                                   opacity=0.4,
                                   color="Num of pregnancies",
                                   color_continuous_scale="rdbu")

# Updating the layout to add a title to the plot.
age_num_sex_partners.update_layout(title="Age vs Number of Sexual Partners")
# Displaying the plot.
age_num_sex_partners.show()
```

Age vs Number of Sexual Partners



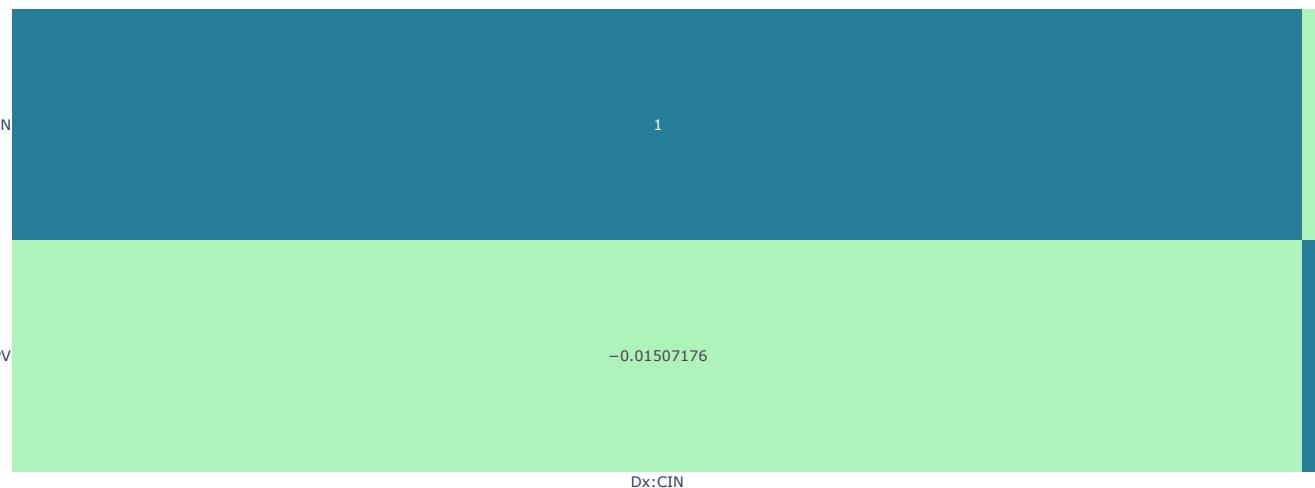
```
# Selecting columns related to diagnoses and number of sexual partners for correlation analysis.
diagnoses_num_partner_compare_cols = [label, 'Dx:HPV', "Number of sexual partners"]
# Calculating the correlation matrix for the selected columns.
corr_matrix = risk_factor_df[diagnoses_num_partner_compare_cols].corr(numeric_only=True)
# Printing the correlation matrix.
# print(corr_matrix)
# Visualizing the correlation matrix using a heatmap with text annotations for correlation values.
diagnoses_num_partner_heatmap = px.imshow(corr_matrix,
                                            aspect="auto",
                                            color_continuous_scale="gnbu",
                                            text_auto=True)
diagnoses_num_partner_heatmap.update_layout(title='HPV vs. Sexual Partners Heatmap')
# Displaying the heatmap.
diagnoses_num_partner_heatmap.show()
```

HPV vs. Sexual Partners Heatmap



```
# Selecting columns related only to diagnoses for correlation analysis.
diagnoses_cols = [label, 'Dx:CIN', 'Dx:HPV']
# Calculating the correlation matrix for the selected diagnoses columns.
diagnoses_corr_matrix = risk_factor_df[diagnoses_cols].corr(numeric_only=True)
# Visualizing the correlation matrix using a heatmap with teal-green color scale and text annotations for correlation values.
diagnoses_heatmap = px.imshow(diagnoses_corr_matrix, aspect="auto", color_continuous_scale="tealgrn", text_auto=True)
# Displaying the heatmap.
diagnoses_heatmap.update_layout(title="Dx:CIN vs Dx:HPV HeatMap")
diagnoses_heatmap.show()
```

## Dx:CIN vs Dx:HPV HeatMap



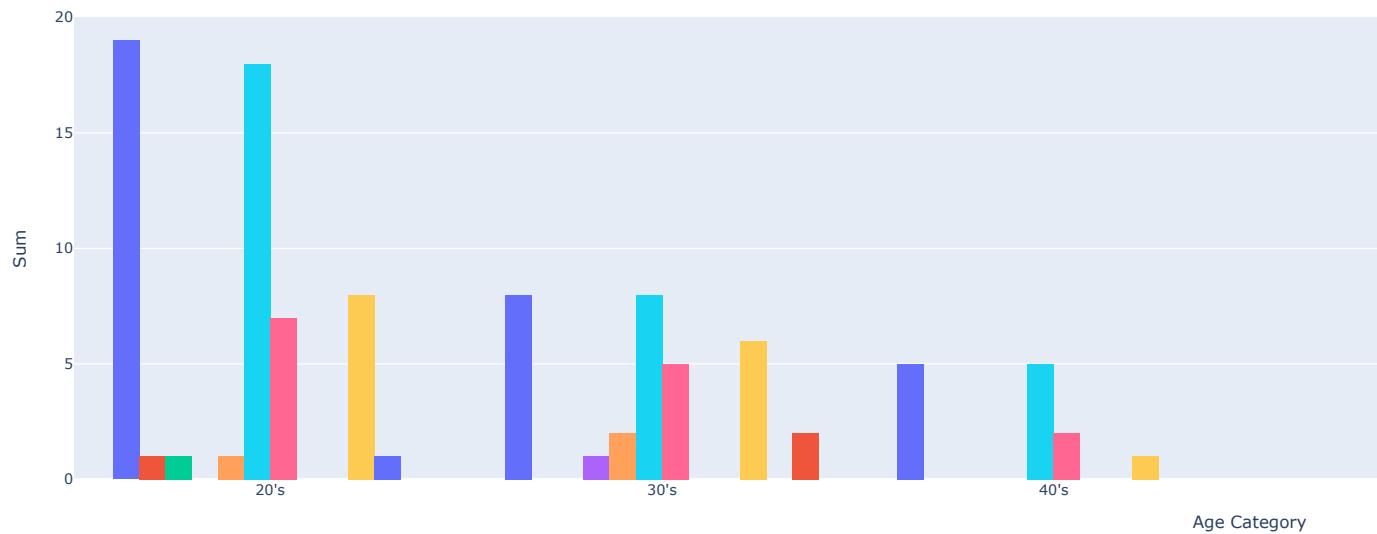
## STDs

```
#data processing - to provide access of std_cols in STD graphs - do we want to add the definitions?
std_cols = {'STDs:condylomatosis',
            'STDs:cervical condylomatosis',
            'STDs:vaginal condylomatosis',
            'STDs:vulvo-perineal condylomatosis',
            'STDs:syphilis',
            'STDs:pelvic inflammatory disease',
            'STDs:genital herpes',
            'STDs:molluscum contagiosum',
            'STDs:AIDS',
            'STDs:HIV',
            'STDs:Hepatitis B',
            'STDs:HPV'}
```

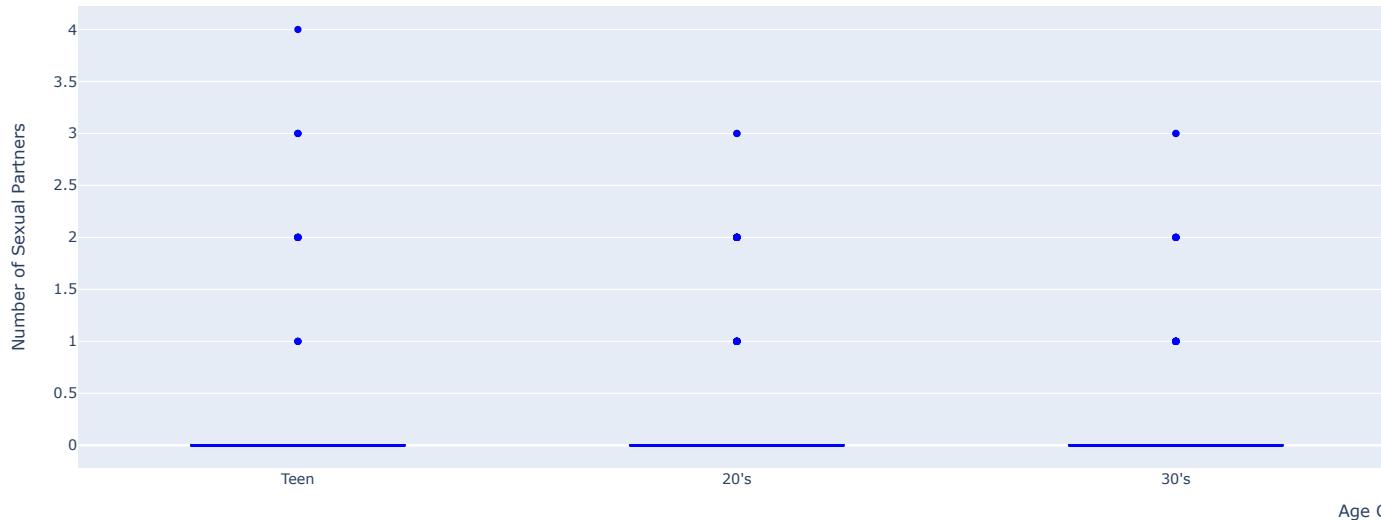
```
#create histogram to understand Sum of STD occurrences across age
fig = px.histogram(std_agg, x = "age_cat",
                  y = list(std_cols),
                  barmode = "group",
                  histfunc = "sum")
fig.update_layout(title = "Sum of STD occurrences across age categories")
fig.update_xaxes(title = "Age Category")
fig.update_yaxes(title = "Sum")
#show plot
fig.show()
#some discrepancies exist
```

## Sum of STD occurrences across age categories

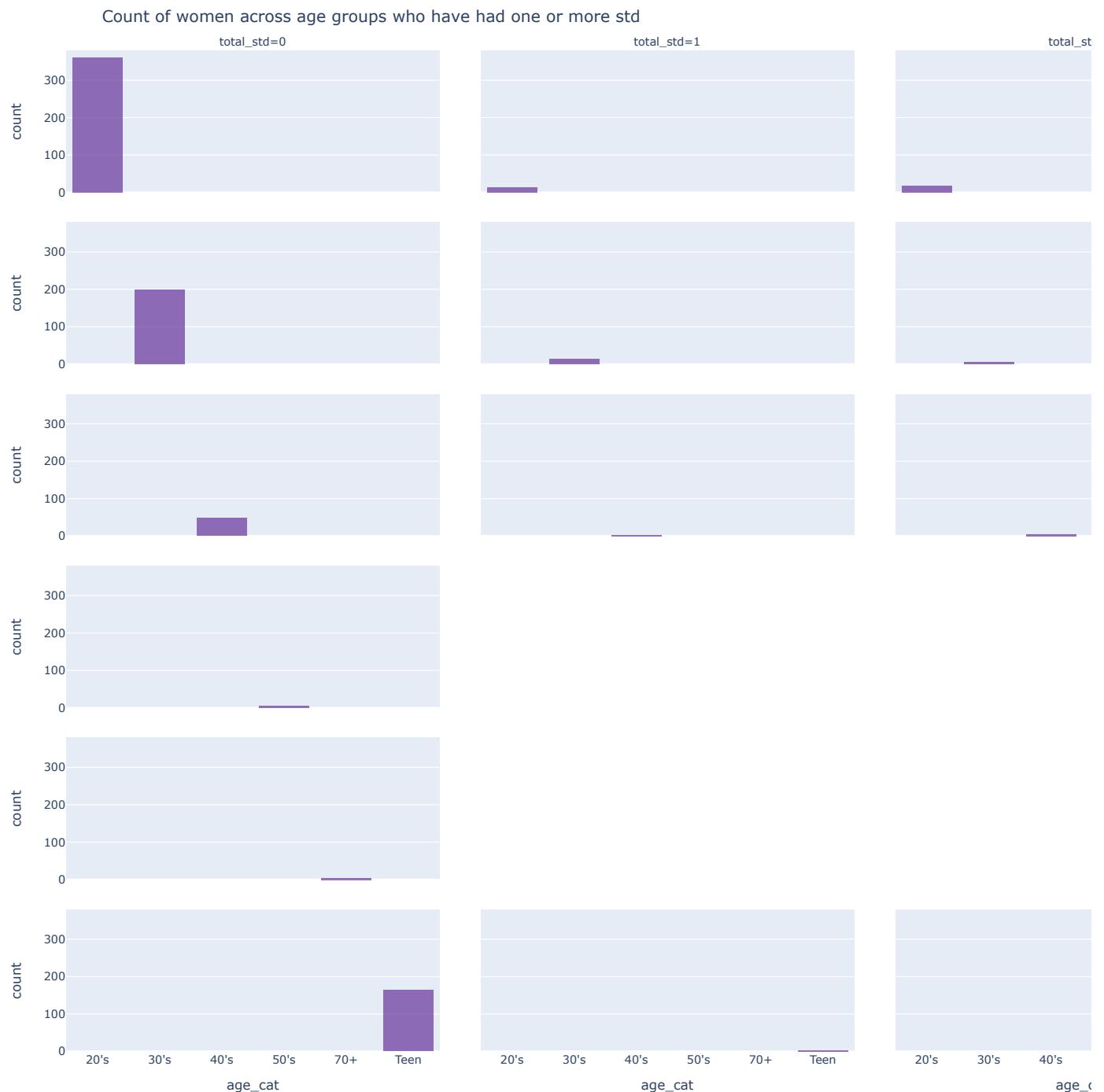


```
#create boxplot to understand Distribution of number of sexual partners per age group
age_num_sex_partners = px.box(risk_factor_df.sort_values(by="Age", ascending=True), x="age_cat", y="total_std",
                               color_discrete_sequence=["blue"], points="outliers",
                               category_orders=["Teenager", "Twenties", "Thirties", "Forties", "Fifties",
                                                 "Seventy and over"])
age_num_sex_partners.update_xaxes(title="Age Category")
age_num_sex_partners.update_yaxes(title="Number of Sexual Partners")
age_num_sex_partners.update_layout(title="Distribution of number of sexual partners per age group")
#show plot
age_num_sex_partners.show()
```

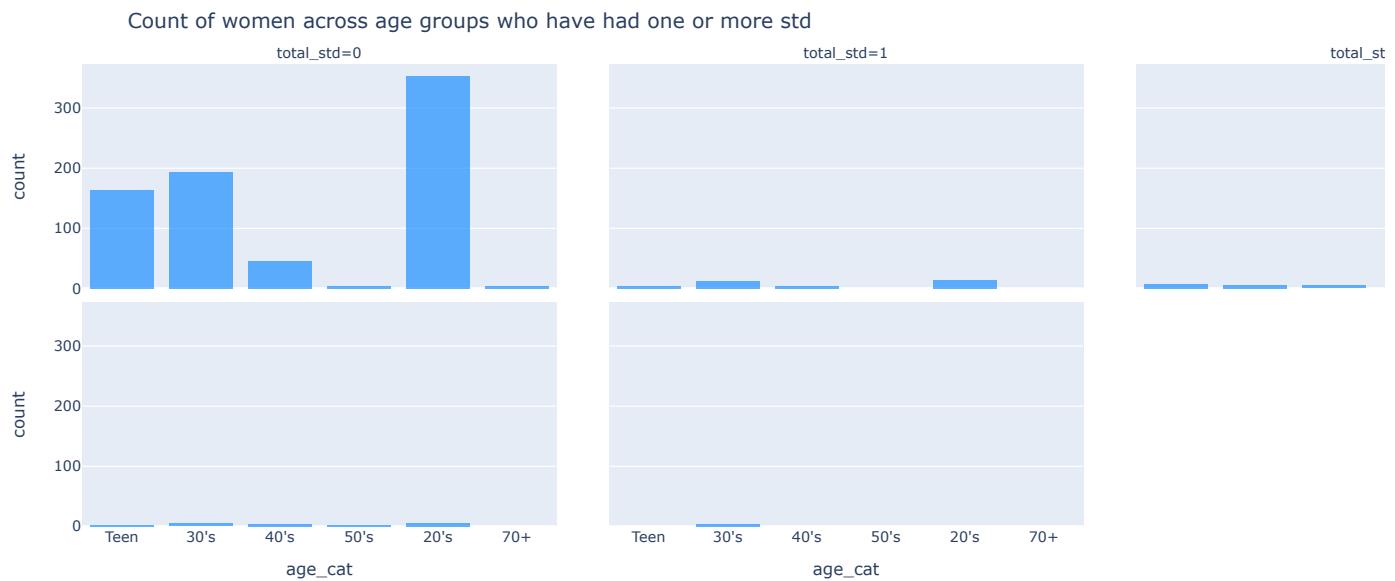
## Distribution of number of sexual partners per age group



```
#create histogram to understand Count of women across age groups who have had one or more std
fig = px.histogram(risk_factor_df.query("total_std>=0").sort_values(by=["total_std", "label"], ascending=True),
                   x="age_cat",
                   facet_col="total_std",
                   facet_row=label,
                   color_discrete_sequence=["rebeccapurple"],
                   opacity=0.7)
fig.update_layout(title="Count of women across age groups who have had one or more std")
fig.update_layout(height=1200)
#show plot
fig.show()
```



```
#create histogram to understand Count of women across age groups who have had one or more std
fig = px.histogram(risk_factor_df.query("total_std>=0").sort_values(by=["total_std","Dx:HPV"], ascending=True),
                   x="age_cat",
                   facet_col="total_std",
                   facet_row="Dx:HPV",
                   color_discrete_sequence=["dodgerblue"],
                   opacity=0.7)
fig.update_layout(title="Count of women across age groups who have had one or more std")
fig.show()
```

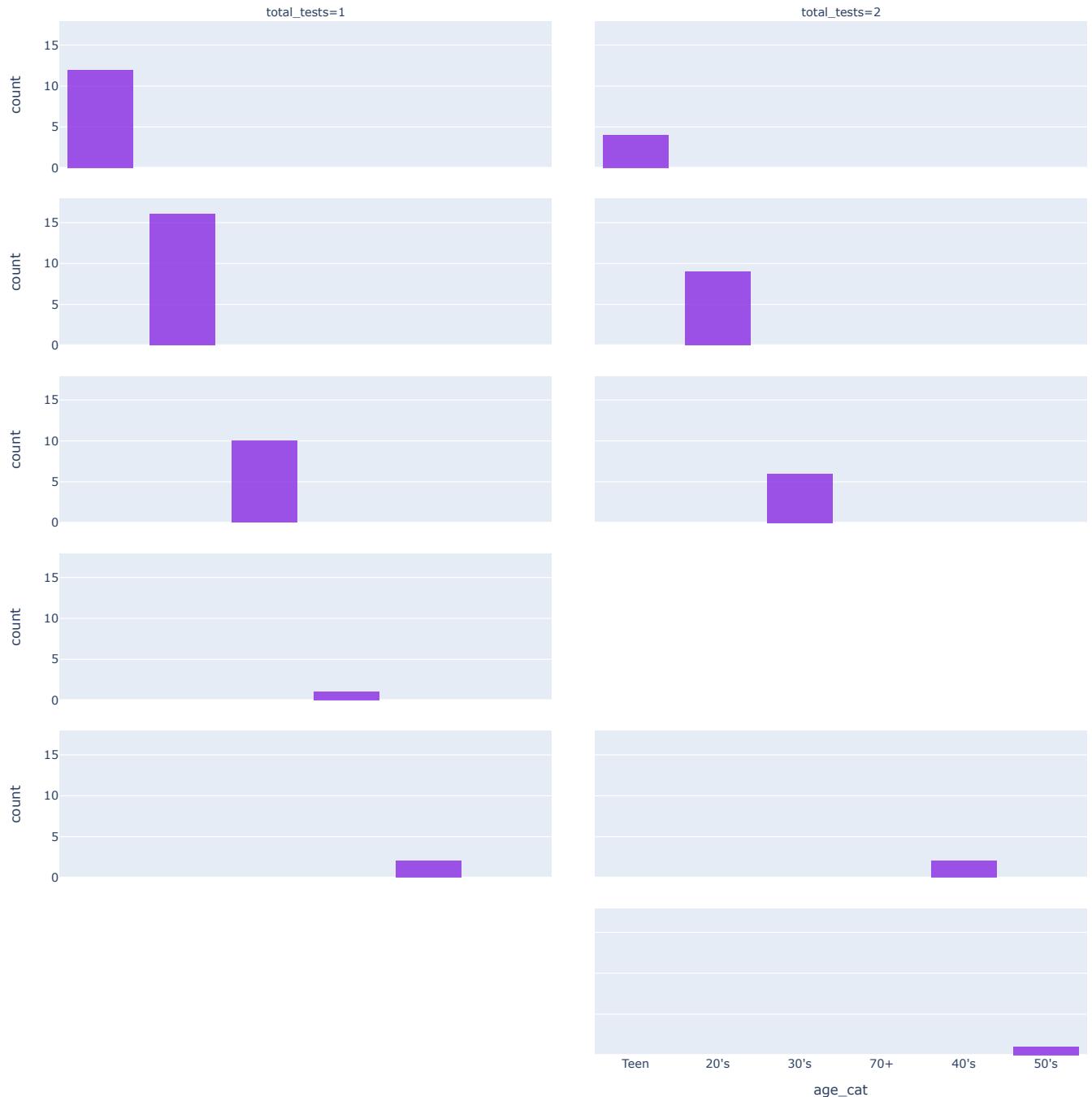


#### ▼ Tests used

Here we observe the number of tests done by patients to determine if they have Cervical Cancer / HPV.

```
fig = px.histogram(risk_factor_df.query("total_tests>0").sort_values(by="total_tests", ascending=True),
                    x="age_cat",
                    facet_col="total_tests",
                    facet_row=label,
                    color_discrete_sequence=["blueviolet"],
                    opacity=0.8)
fig.update_layout(title="Count of women across age groups who have had one or more test by Age Category")
fig.update_layout(height=1200)
fig.show()
```

Count of women across age groups who have had one or more test by Age Category

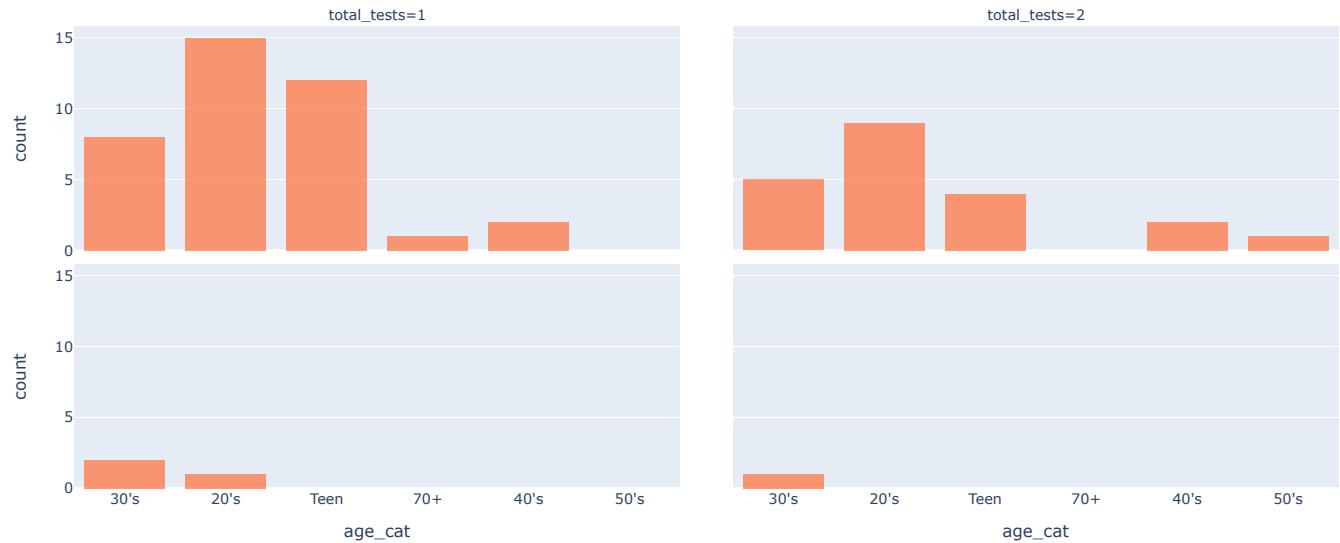


```

fig = px.histogram(risk_factor_df.query("total_tests>0").sort_values(by=["total_tests","Dx:HPV"], ascending=True),
                    x="age_cat",
                    facet_col="total_tests",
                    facet_row="Dx:HPV",
                    color_discrete_sequence=["coral"],
                    opacity=0.8)
fig.update_layout(title="Count of women across age groups who have had one or more test by Dx:HPV")
fig.show()

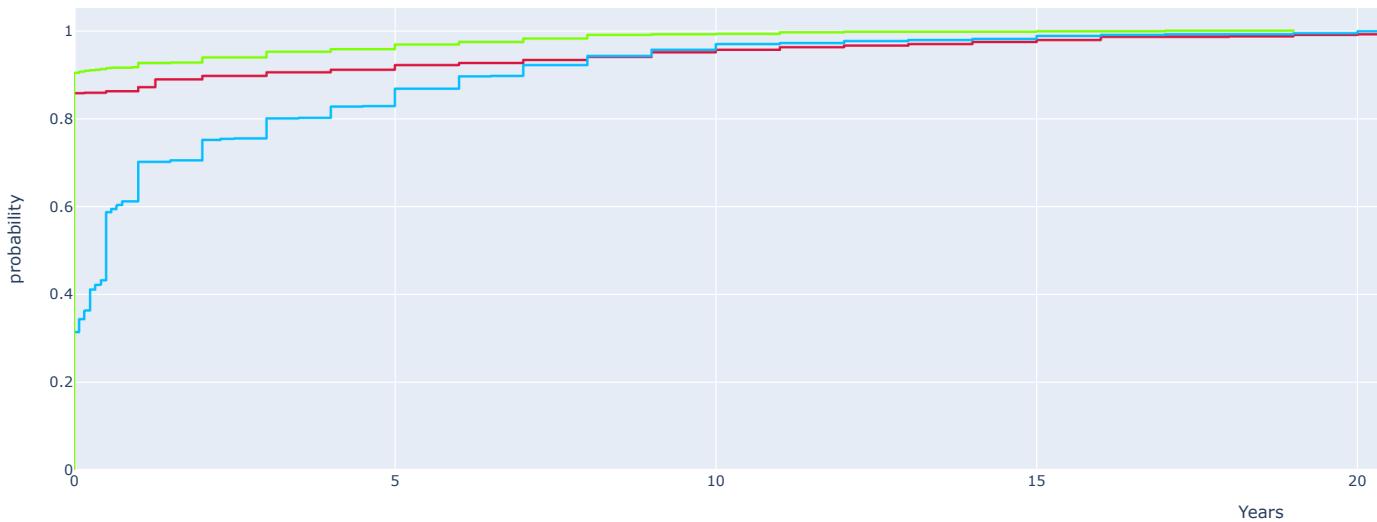
```

## Count of women across age groups who have had one or more test by Dx:HPV



```
fig = px.ecdf(risk_factor_df, x=["Smokes (years)",  
                                 "Hormonal Contraceptives (years)",  
                                 "IUD (years)"],  
               color_discrete_sequence=["crimson", "deepskyblue", "chartreuse"])  
fig.update_xaxes(title="Years")  
fig.update_layout(title="ECDF Plot")  
fig.show()
```

ECDF Plot



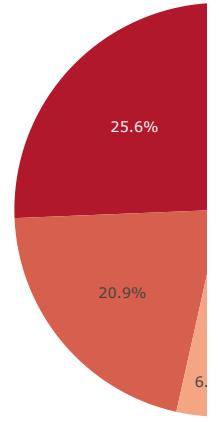
```

age_category_range = {
    "Age<12": "Child",
    "Age>=12 & Age<20": "Teen",
    "Age>=20 & Age<30": "20's",
    "Age>=30 & Age<40": "30's",
    "Age>=40 & Age<50": "40's",
    "Age>=50 & Age<60": "50's",
    "Age>=60 & Age<70": "60's",
    "Age>=70": "70+"
}
age_prop_dict = {}
col = "Age" # Just to get the count
for age_range, category in age_category_range.items():
    age_prop_dict[category] = risk_factor_df.query(age_range)[col].count() / len(risk_factor_df)

proportion_samples_df = pd.DataFrame.from_dict(age_prop_dict, orient="index",
                                               columns=[ "Sample Proportion"])
proportion_samples_df = proportion_samples_df.reset_index()
proportion_samples_df.columns = proportion_samples_df.columns.str.replace("index","Category")
fig = px.pie(proportion_samples_df,
              values='Sample Proportion',
              names="Category",
              title='Age Category proportion of women sampled',color_discrete_sequence=px.colors.sequential.RdBu)
fig.show()
proportion_samples_df

```

Age Category proportion of women sampled



	Category	Sample Proportion
0	Child	0.000000
1	Teen	0.208625
2	20's	0.459207
3	30's	0.256410
4	40's	0.065268
5	50's	0.005828
6	60's	0.000000
7	70+	0.004662

```

fig = make_subplots(rows=1, cols=2, specs=[[{'type': 'domain'}, {'type': 'domain'}]],
                     subplot_titles=["Cancer", "HPV"])
fig.add_trace(go.Pie(labels=risk_factor_df["age_cat"],
                      values=risk_factor_df[label],
                      name="Cancer", marker_colors=px.colors.sequential.RdBu),
              1, 1)
fig.add_trace(go.Pie(labels=risk_factor_df["age_cat"],
                      values=risk_factor_df["Dx:HPV"],
                      name="HPV", marker_colors=px.colors.sequential.RdBu),
              1, 2)
fig.update_traces(hole=.0, hoverinfo="label+percent+name")

fig.update_layout(
    title_text="Proportion of women across age categories with a diagnosis of Cancer, HPV",
)
fig.show()

```

Proportion of women across age categories with a diagnosis of Cancer, HPV

Cancer

Contraceptive

```

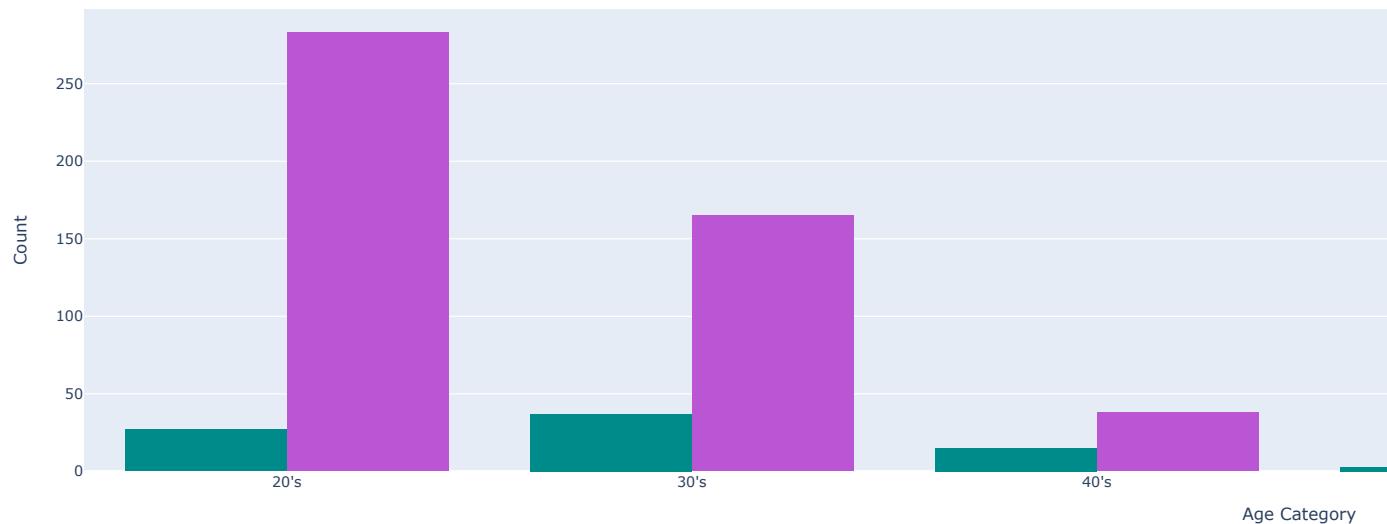
df_hormonal_compariosn = risk_factor_df.groupby(["age_cat"], as_index=False)[["IUD", "Hormonal Contraceptives"]].sum()
fig = px.histogram(df_hormonal_compariosn, x="age_cat", y=["IUD", "Hormonal Contraceptives"], barmode="group"
                   , color_discrete_sequence=["darkcyan", "mediumorchid"])

fig.update_xaxes(title="Age Category")
fig.update_yaxes(title="Count")
fig.update_layout(title="Age Ranges of women who use Contraceptives")

fig.show()

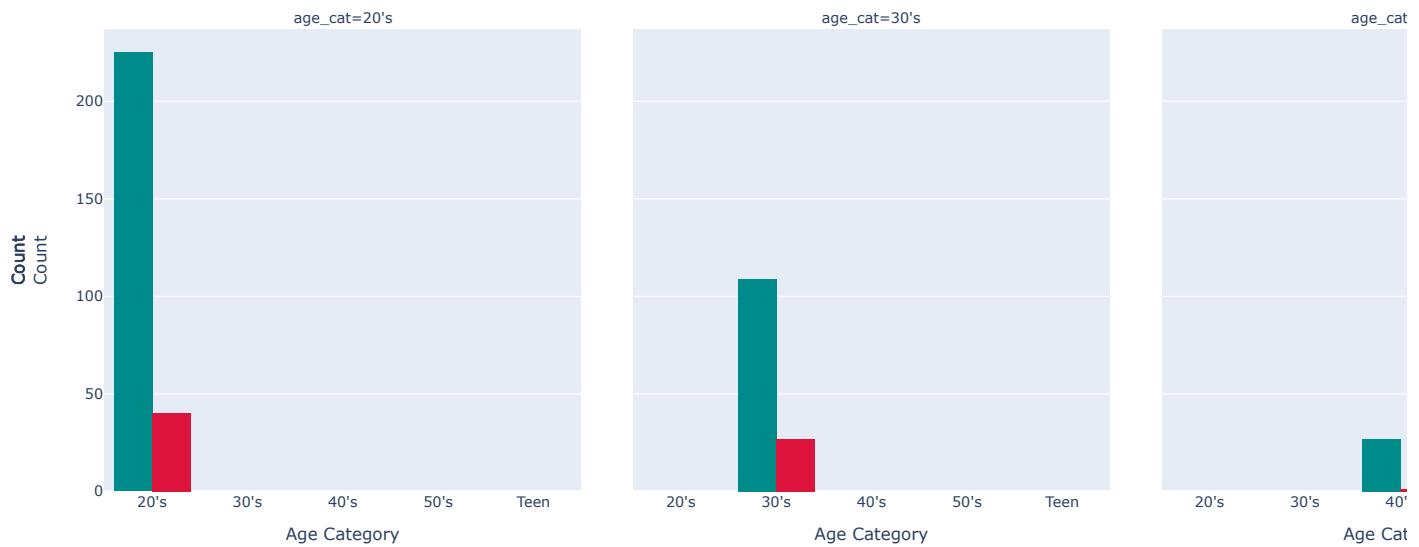
```

## Age Ranges of women who use Contraceptives

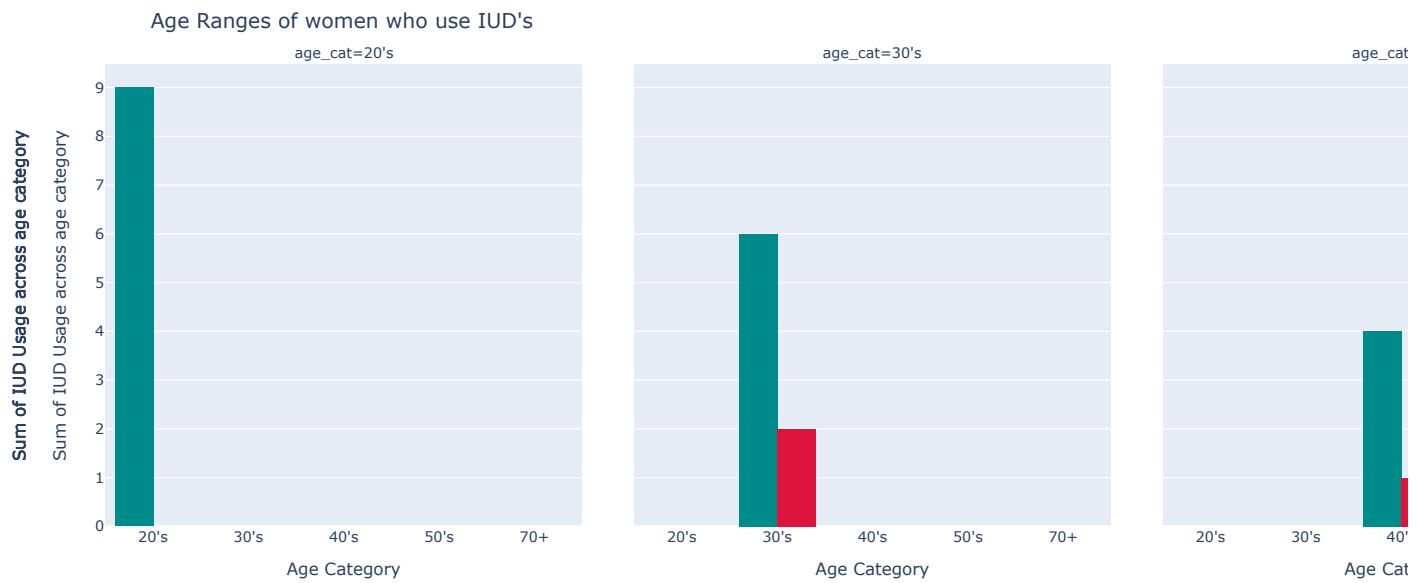


```
df_hormonal_contraceptives = risk_factor_df[
    (risk_factor_df["Hormonal Contraceptives"] == 1) & (risk_factor_df["IUD"] == 0)]
df_hormonal_contraceptives = df_hormonal_contraceptives.sort_values(by=["Smokes", "label"])
fig = px.histogram(df_hormonal_contraceptives, x="age_cat", color="Smokes", barmode="group", facet_col=label,
                    color_discrete_sequence=["darkcyan", "crimson"])
fig.update_xaxes(title="Age Category")
fig.update_yaxes(title="Count")
fig.update_layout(title="Age Ranges of women who use Hormonal Contraceptives")
# fig.for_each_annotation(lambda a: a.update(text=a.text.split(":")[-1]))
fig.show()
```

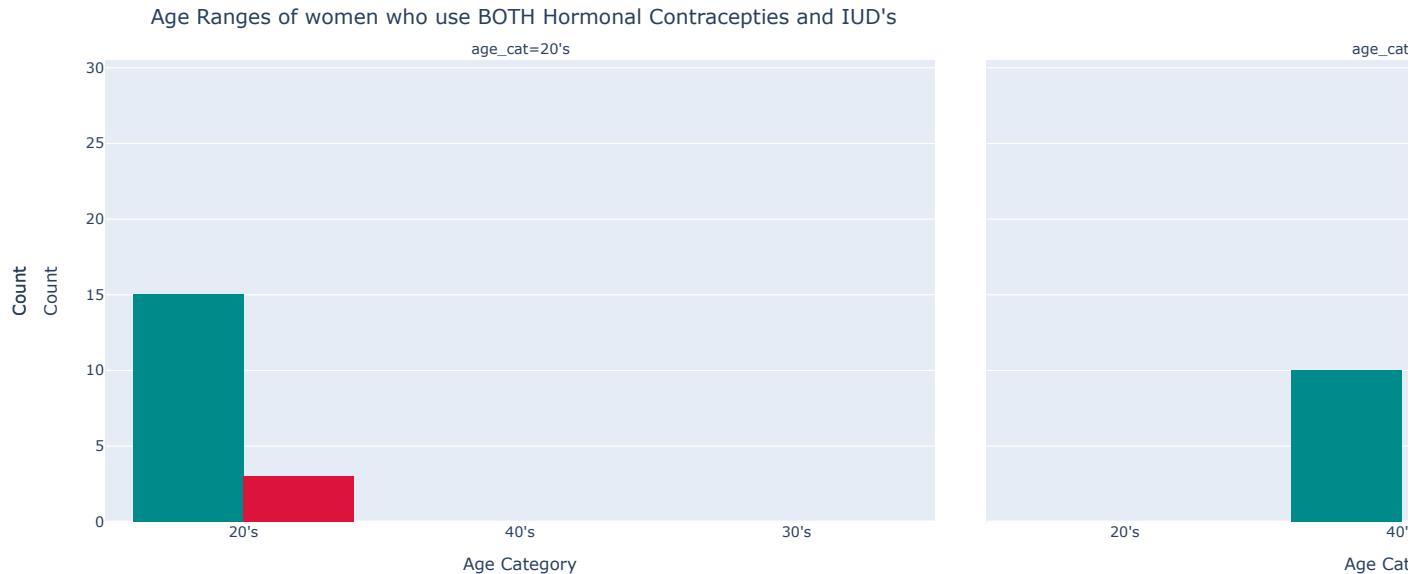
## Age Ranges of women who use Hormonal Contraceptives



```
df_IUD_contraceptives = risk_factor_df[(risk_factor_df["Hormonal Contraceptives"] == 0) & (risk_factor_df["IUD"] == 1)]
df_IUD_contraceptives = df_IUD_contraceptives.sort_values(by=["Smokes", "label"], ascending=True)
fig = px.histogram(df_IUD_contraceptives, x="age_cat", color="Smokes", barmode="group", facet_col=label,
                    color_discrete_sequence=["darkcyan", "crimson"])
fig.update_xaxes(title="Age Category")
fig.update_yaxes(title="Sum of IUD Usage across age category")
fig.update_layout(title="Age Ranges of women who use IUD's")
fig.show()
```



```
df_both_contraceptives = risk_factor_df[(risk_factor_df["Hormonal Contraceptives"] == 1) & (risk_factor_df["IUD"] == 1)]
df_both_contraceptives = df_both_contraceptives.sort_values(by="Smokes")
fig = px.histogram(df_both_contraceptives, x="age_cat", color="Smokes", barmode="group", facet_col=label,
                    color_discrete_sequence=["darkcyan", "crimson"])
fig.update_xaxes(title="Age Category")
fig.update_yaxes(title="Count")
fig.update_layout(title="Age Ranges of women who use BOTH Hormonal Contracepties and IUD's")
fig.show()
```



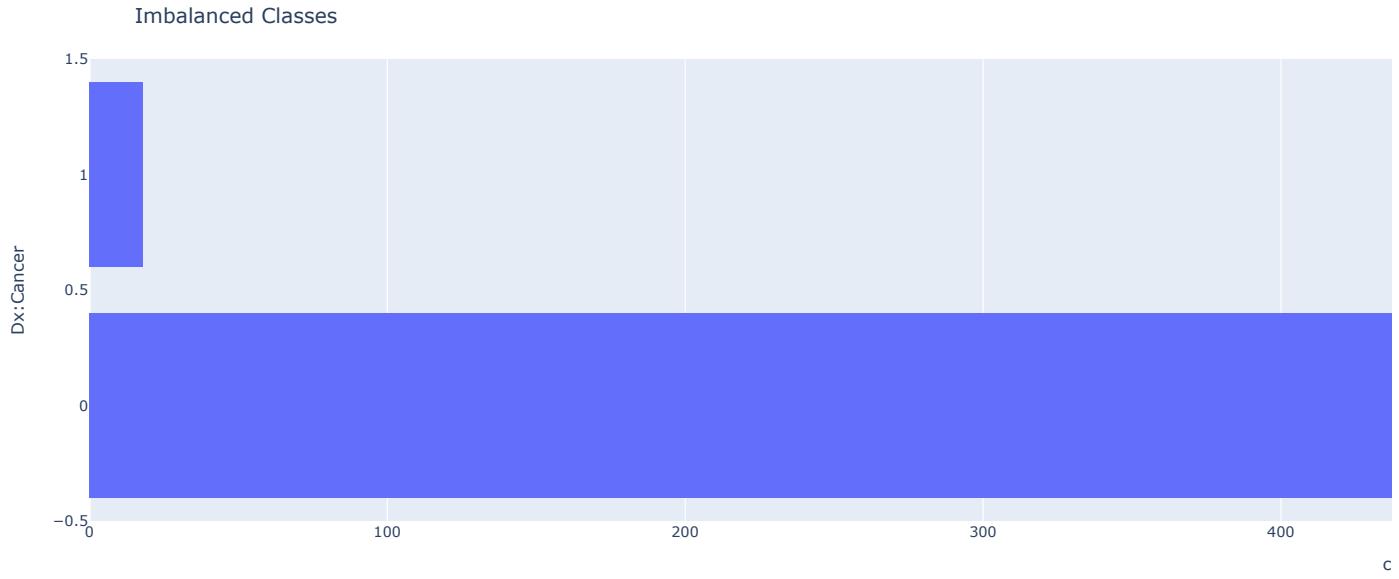
## ADASYN

```
test=risk_factor_df[['Number of sexual partners', 'First sexual intercourse', 'Num of pregnancies', 'Smokes', 'Dx', 'Hormonal Contraceptives',
with open('summary.tex','w') as tf:
    tf.write(test.round(2).to_latex())
risk_factor_df.columns

Index(['Age', 'Number of sexual partners', 'First sexual intercourse',
       'Num of pregnancies', 'Smokes', 'Smokes (years)', 'Smokes (packs/year)',
       'Hormonal Contraceptives', 'Hormonal Contraceptives (years)', 'IUD',
       'IUD (years)', 'STDs', 'STDs (number)', 'STDs:condylomatosis',
       'STDs:cervical condylomatosis', 'STDs:vaginal condylomatosis',
       'STDs:vulvo-perineal condylomatosis', 'STDs:syphilis',
```

```
'STDs:pelvic inflammatory disease', 'STDs:genital herpes',
'STDs:molluscum contagiosum', 'STDs:AIDS', 'STDs:HIV',
'STDs:Hepatitis B', 'STDs:HPV', 'STDs: Number of diagnosis',
'STDs: Time since first diagnosis', 'STDs: Time since last diagnosis',
'Dx:Cancer', 'Dx:CIN', 'Dx:HPV', 'Dx', 'Hinselmann', 'Schiller',
'Cytology', 'Biopsy', 'age_cat', 'total_std', 'total_tests'],
dtype='object')
```

```
label="Dx:Cancer"
dx_cancer = px.histogram(risk_factor_df, y=label)
dx_cancer.update_layout(bargap=0.2)
dx_cancer.update_layout(title = "Imbalanced Classes")
dx_cancer.show()
```



Here we use ADASYN to balance the dataset

```
unbalanced_risk_factor_df = risk_factor_df
X = risk_factor_df.drop([label, "age_cat"], axis=1)
y = risk_factor_df[label].copy()
adasyn = ADASYN(random_state=42)
x_adasyn,y_adasyn = adasyn.fit_resample(X,y)
risk_factor_df = x_adasyn.join(y_adasyn)
```

Save ADASYN dataset

```
risk_factor_df["age_cat"] = risk_factor_df["Age"].apply(age_cat)
save_data(risk_factor_df, '/content/drive/My Drive/DL4H_Sp24_Final_Project/balanced_risk_factors_cervical_cancer.csv')
```

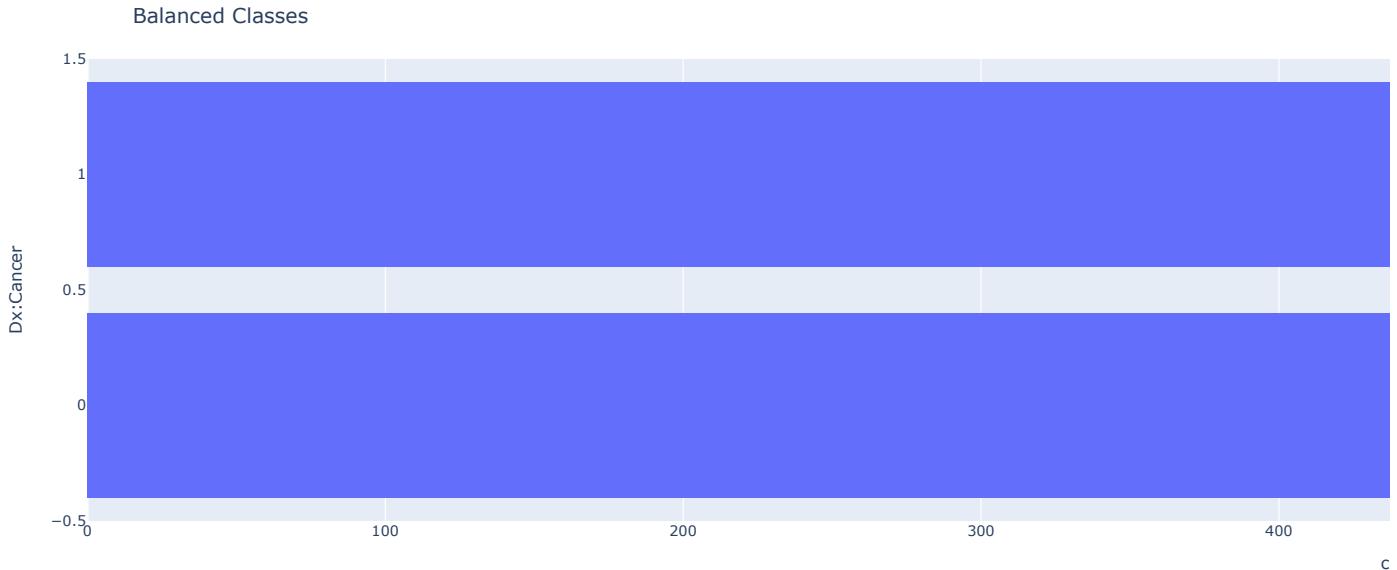
Save checkpoint granted

#### ✓ Checkpoint: Load Balanced data

```
try:
    data_dir = '/content/drive/My Drive/DL4H_Sp24_Final_Project/balanced_risk_factors_cervical_cancer.csv'
    risk_factor_df = load_data(data_dir)
    have_access = True
except:
    have_access = False
    data_dir = root + '/balanced_risk_factors_cervical_cancer.csv'
    # gdown.download('https://drive.google.com/file/d/1-4EiQdYBbae16azaiZry7Gwhpq7XhwEf/view?usp=share_link', data_dir, format='csv', fuzzy=True)
    risk_factor_df = load_data(data_dir)
    print("No access, Used Gdown!")
risk_factor_df
label="Dx:Cancer"

No access, Used Gdown!
```

```
dx_cancer = px.histogram(risk_factor_df, y=label)
dx_cancer.update_layout(bargap=0.2)
dx_cancer.update_layout(title = "Balanced Classes")
dx_cancer.show()
```



## ✓ Checkpoint: Train Test Split

Stratifying the data on Age Category

### ✓ Unbalanced

```
unbalanced_train_set = None
unbalanced_test_set = None
#Stratify the data
# 20% in test and 80% in train
unbalanced_split = StratifiedShuffleSplit(n_splits=1, test_size=0.2, random_state=42)
for train_idx, test_idx in unbalanced_split.split(unbalanced_risk_factor_df, unbalanced_risk_factor_df["age_cat"]):
    unbalanced_train_set = unbalanced_risk_factor_df.loc[train_idx]
    unbalanced_test_set = unbalanced_risk_factor_df.loc[test_idx]
unbalanced_cols_to_drop = ["age_cat","total_std","total_tests"]
for set_ in (unbalanced_train_set, unbalanced_test_set):
    for col in unbalanced_cols_to_drop:
        set_.drop(col, axis=1, inplace=True)

unbalanced_X_train = unbalanced_train_set.drop(label, axis=1)
unbalanced_y_train = unbalanced_train_set[label].copy()

unbalanced_X_test = unbalanced_test_set.drop(label, axis=1)
unbalanced_y_test = unbalanced_test_set[label].copy()

unbalanced_X_test.reset_index(drop=True, inplace=True)
unbalanced_y_test.reset_index(drop=True, inplace=True)
unbalanced_X_train.reset_index(drop=True, inplace=True)
unbalanced_y_train.reset_index(drop=True, inplace=True)

print("unbalanced_X_test length: ", len(unbalanced_X_test))
print("unbalanced_X_train length: ", len(unbalanced_X_train))
print("unbalanced_Y_test length: ", len(unbalanced_y_test))
print("unbalanced_Y_train length: ", len(unbalanced_y_train))

unbalanced_X_test length: 172
unbalanced_X_train length: 686
unbalanced_Y_test length: 172
unbalanced_Y_train length: 686
```

### ✓ Balanced

```

train_set = None
test_set = None
#Stratify the data
# 20% in test and 80% in train
split = StratifiedShuffleSplit(n_splits=1, test_size=0.2, random_state=42)
for train_idx, test_idx in split.split(risk_factor_df, risk_factor_df["age_cat"]):
    train_set = risk_factor_df.loc[train_idx]
    test_set = risk_factor_df.loc[test_idx]
cols_to_drop = ["age_cat", "total_std", "total_tests"]
for set_ in (train_set, test_set):
    for col in cols_to_drop:
        set_.drop(col, axis=1, inplace=True)

X_train = train_set.drop(label, axis=1)
y_train = train_set[label].copy()

X_test = test_set.drop(label, axis=1)
y_test = test_set[label].copy()

X_test.reset_index(drop=True, inplace=True)
y_test.reset_index(drop=True, inplace=True)
X_train.reset_index(drop=True, inplace=True)
y_train.reset_index(drop=True, inplace=True)

print("X_test length: ", len(X_test))
print("X_train length: ", len(X_train))
print("Y_test length: ", len(y_test))
print("Y_train length: ", len(y_train))

X_test length: 336
X_train length: 1341
Y_test length: 336
Y_train length: 1341

```

## ▼ Save sets

```

#without random var
X_test.to_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/X_test.csv')
y_test.to_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/y_test.csv')
X_train.to_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/X_train.csv')
y_train.to_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/y_train.csv')

```

---

```

OSSError                                     Traceback (most recent call last)
<ipython-input-46-b509046c6f98> in <cell line: 2>()
      1 #without random var
----> 2 X_test.to_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/X_test.csv')
      3 y_test.to_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/y_test.csv')
      4 X_train.to_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/X_train.csv')
      5 y_train.to_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/y_train.csv')


```

---

```

/usr/local/lib/python3.10/dist-packages/pandas/io/common.py in check_parent_directory(path)
    598
    599
--> 600 @overload
    601     def get_handle(
    602         path_or_buf: FilePath | BaseBuffer,

```

```
OSSError: Cannot save file into a non-existent directory: '/content/drive/My Drive/DL4H_Sp24_Final_Project'
```

## ▼ Checkpoint: Model Setup

We will be comparing different models: RF, SVM, LR, KNN, MLP

### ▼ Model 1: Logistic Regression.

This is a simple linear model and does not have layers.

The sigmoid function is used as its activation.

lbfgs is used as the solver with L2 regularization

The default max\_iter for convergence is 100.

```
param_grid = {'C': np.logspace(-5, 8, 15)}

logreg = LogisticRegression()
logreg_cv = GridSearchCV(logreg, param_grid, cv=10, refit=True)
unbalanced_logreg_cv = GridSearchCV(logreg, param_grid, cv=10, refit=True)
```

#### ✓ Model 2: RandomForestClassifier

Ensemble machine learning model using groups of decision trees to reduce overfitting

The default n\_estimators is 100

Default criterion = gini

Convergence ends when all leaves are pure or until each leaf is equal to min\_samples\_leaf (by default set to 2)

```
rnd_clf = RandomForestClassifier()
unbalanced_rnd_clf = RandomForestClassifier()
```

#### ✓ Model 3: KNeighborsClassifier

A machine learning iterative classification method that uses a distance function to group similar data

n\_neighbors (number of surrounding data points to consider) is 5 by default

```
knn_clf = KNeighborsClassifier()
knn_param_grid = {"n_neighbors": list(np.arange(1, 100, 2))}
knn_clf_cv = GridSearchCV(knn_clf, knn_param_grid, cv=10, refit=True)
unbalanced_knn_clf_cv = GridSearchCV(knn_clf, knn_param_grid, cv=10, refit=True)
```

#### ✓ MODEL 4: SupportVectorClassifier

Support vector models are classification algorithm that uses hyperplanes to classify data points using a maximum margin between decision boundaries and the closest data points.

The regularization parameter C is set to 1 by default.

The kernel type is set to 'rbf' (radial basis function) by default

```
svm_clf = SVC()
svc_param_grid = {'C': np.logspace(-3, 2, 6), 'gamma': np.logspace(-3, 2, 6), }
svm_clf_cv = GridSearchCV(svm_clf, svc_param_grid, cv=5, refit=True)
unbalanced_svm_clf_cv = GridSearchCV(svm_clf, svc_param_grid, cv=5, refit=True)
```

#### ✓ MODEL 5: MLPClassifier

MLPs are neural networks used for pattern detection.

They consist of 3 layers of nodes, an input layer, a hidden layer, and an output layer.

The default max\_iter is 200.

The optimizer is 'Adam'

Each node uses a nonlinear activation function. By default this is ReLu for the hidden layer. For the output layer, softmax is used by default for multi-class classification problems and logistic for binary classification problems.

Backpropagation and gradient descent is used to train and minimize loss.

```
nn_clf = MLPClassifier()
unbalanced_nn_clf = MLPClassifier()
```

#### ✓ Set up training metrics

```

# metrics to evaluate my model
# Define column names for the summary DataFrame
col_names = ["Classifier Name", "Accuracy Score", "Precision Score", "Recall Score", "F1 Score", "AUROC"]
# Initialize the summary DataFrame with predefined column names
unbalanced_summary_df = pd.DataFrame(columns=col_names)

# Lists to store the metrics for each estimator
unbalanced_est_name = []
unbalanced_est_acc = []
unbalanced_precision_score = []
unbalanced_recall_score = []
unbalanced_f1score = []
unbalanced_est_conf_matrix = []
unbalanced_roc = []

# List of tuples containing the classifiers to evaluate and their respective variable names
unbalanced_estimators = [
    ("UnbalancedLogisticRegression", unbalanced_logreg_cv),
    ("UnbalancedRandomForestClassifier", unbalanced_rnd_clf),
    ("UnbalancedKNeighborsClassifier", unbalanced_knn_clf_cv),
    ("UnbalancedSupportVectorClassifier", unbalanced_svm_clf_cv),
    ("UnbalancedMLPClassifier", unbalanced_nn_clf)
]

unbalanced_models = ['UnbalancedLogisticRegression.pkl',
                     'UnbalancedRandomForestClassifier.pkl',
                     'UnbalancedKNeighborsClassifier.pkl',
                     'UnbalancedSupportVectorClassifier.pkl',
                     'UnbalancedMLPClassifier.pkl']

summary_df = pd.DataFrame(columns=col_names)

# Lists to store the metrics for each estimator
est_name = []
est_acc = []
precision_score = []
recall_score = []
f1score = []
est_conf_matrix = []
roc = []

# List of tuples containing the classifiers to evaluate and their respective variable names
estimators = [
    ("LogisticRegression", logreg_cv),
    ("RandomForestClassifier", rnd_clf),
    ("KNeighborsClassifier", knn_clf_cv),
    ("SupportVectorClassifier", svm_clf_cv),
    ("MLPClassifier", nn_clf)
]
balanced_models = ['LogisticRegression.pkl',
                   'RandomForestClassifier.pkl',
                   'KNeighborsClassifier.pkl',
                   'SupportVectorClassifier.pkl',
                   'MLPClassifier.pkl']

```

## ▼ Model Training

**Hyperparameters:** Three examples of hyperparameters we used are 'C' (regularization constant), type of kernel ('rbf'), gamma (kernel coefficient) in the Support Vector Classifier Model.

**Computational Requirements:** Dataset is small enough to compute on an 8 GB 2133 MHz LPDDR3 2.3 GHz Dual-Core Intel Core i5. Average run time for training is < 2 minutes. We used default epochs. For logistic regression this 100 and for MLP this is 200, unless convergence is reached earlier.

The training for the Local explainability models took hours however and we had to sample to get them done.

## ▼ Unbalanced Training (Ablation)

```

# Iterate over the estimators to train
for i in range(len(unbalanced_estimators)):
    unbalanced_clf_name, unbalanced_clf = unbalanced_estimators[i] # Unpack the classifier name and the classifier object
    print("Training ", unbalanced_clf_name)
    unbalanced_clf.fit(unbalanced_X_train, unbalanced_y_train) # Train the classifier
    gd_model_name = root + unbalanced_clf_name + '.pkl'
    with open(gd_model_name, 'wb') as file:
        pickle.dump(unbalanced_clf, file)
    unbalanced_clf_name, unbalanced_clf = '', ''

```

```

Training UnbalancedLogisticRegression
Training UnbalancedRandomForestClassifier
Training UnbalancedNeighborsClassifier
Training UnbalancedSupportVectorClassifier
Training UnbalancedMLPClassifier

```

## ▼ Balanced Training

```

for i in range(len(estimators)):
    clf_name, clf = estimators[i] # Unpack the classifier name and the classifier object
    print("Training ", clf_name)
    clf.fit(X_train, y_train) # Train the classifier
    gd_model_name = root + clf_name + '.pkl'
    with open(gd_model_name, 'wb') as file:
        pickle.dump(clf, file)
    clf_name, clf = '', ''

```

```

Training LogisticRegression
Training RandomForestClassifier
Training KNeighborsClassifier
Training SupportVectorClassifier
Training MLPClassifier

```

Double-click (or enter) to edit

## ▼ Checkpoint: Result

### ▼ Download pickle models with gdown

```

# LogisticRegression
unbalanced_models[0] = root +'/UnbalancedLogisticRegression.pkl'
balanced_models[0] = root +'LogisticRegression.pkl'
# gdown.download('https://drive.google.com/file/d/1-4D7VkJQ4qewUnyrrzPw1izMk9WjMvQ13D/view?usp=share_link', unbalanced_models[0], fuzzy=True,quiet
# gdown.download('https://drive.google.com/file/d/1-94qCsT0VdS-Cv0237Z0TeUWCouKDevl/view?usp=share_link', balanced_models[0], fuzzy=True,quiet
# # RandomForestClassifier
unbalanced_models[1] = root +'UnbalancedRandomForestClassifier.pkl'
balanced_models[1] = root +'RandomForestClassifier.pkl'
# gdown.download('https://drive.google.com/file/d/1-PBTxxalNfxQNKpX8Bg9ojFRtPGEsvbw/view?usp=share_link', unbalanced_models[1], fuzzy=True,quiet
# gdown.download('https://drive.google.com/file/d/1-Qdk5tk2RCLhbfbVW400S2qBI6ikStRBh/view?usp=share_link', balanced_models[1], fuzzy=True,quiet
# # KNeighborsClassifier
unbalanced_models[2] = root +'UnbalancedKNeighborsClassifier.pkl'
balanced_models[2] = root +'KNeighborsClassifier.pkl'
# gdown.download('https://drive.google.com/file/d/1-Rg4cRA6NdtPeHPFnablplZ0T7e3230g/view?usp=share_link', unbalanced_models[2], fuzzy=True,quiet
# gdown.download('https://drive.google.com/file/d/1-TKog0oufiIcfCJtv_g0dYTiw1rk6VknN/view?usp=share_link', balanced_models[2], fuzzy=True,quiet
# # SupportVectorClassifier
unbalanced_models[3] = root +'UnbalancedSupportVectorClassifier.pkl'
balanced_models[3] = root +'SupportVectorClassifier.pkl'
# gdown.download('https://drive.google.com/file/d/1_g0BZHdpupPP9x1j0jKWJ-8fVZe4sTPkA/view?usp=sharing', unbalanced_models[3], fuzzy=True,quiet=
# gdown.download('https://drive.google.com/file/d/1-3sNvATHD55evt_9nSzf3nBP6XWLknjL/view?usp=sharing', balanced_models[3], fuzzy=True,quiet=Tr
# # MLPClassifier
unbalanced_models[4] = root +'UnbalancedMLPClassifier.pkl'
balanced_models[4] = root +'MLPClassifier.pkl'
# gdown.download('https://drive.google.com/file/d/1-3P6L-WKDrfMNngwp372f3vgY9Px0SEIm/view?usp=sharing', unbalanced_models[4], fuzzy=True,quiet=
# gdown.download('https://drive.google.com/file/d/1-DmdcIFHJFKUtAhhVw1XbVlwbffjOpWS2/view?usp=sharing', balanced_models[4], fuzzy=True,quiet=Tr

```

## ▼ Model Execution

### ▼ Unbalanced evaluation (ablation)

```

# Iterate over the trained models to evaluate each one
for i in range(len(unbalanced_estimators)):
    with open(unbalanced_models[i], 'rb') as file:
        downloaded_model = pickle.load(file)
    unbalanced_clf_name, _ = unbalanced_estimators[i]
    unbalanced_y_pred = downloaded_model.predict(unbalanced_X_test) # Predict the test set outcomes
    # Calculate the AUROC score and append it to the roc list
    unbalanced_roc.append(roc_auc_score(unbalanced_y_test, unbalanced_y_pred, average=None))

    # Append classifier name to the est_name list
    unbalanced_est_name.append(unbalanced_clf_name)

    # Calculate and append accuracy to the est_acc list
    unbalanced_est_acc.append(accuracy_score(unbalanced_y_test, unbalanced_y_pred))

    # Calculate precision, recall, and F1 scores and append them to their respective lists
    unbalanced_scores = precision_recall_fscore_support(unbalanced_y_test, unbalanced_y_pred, average="weighted")
    unbalanced_precision_score.append(unbalanced_scores[0])
    unbalanced_recall_score.append(unbalanced_scores[1])
    unbalanced_f1score.append(unbalanced_scores[2])

    # Append the confusion matrix for each classifier to the est_conf_matrix list
    unbalanced_est_conf_matrix.append(confusion_matrix(unbalanced_y_test, unbalanced_y_pred))

# Populate the summary DataFrame with the collected metrics for each classifier
unbalanced_summary_df[col_names[0]] = unbalanced_est_name
unbalanced_summary_df[col_names[1]] = unbalanced_est_acc
unbalanced_summary_df[col_names[2]] = unbalanced_precision_score
unbalanced_summary_df[col_names[3]] = unbalanced_recall_score
unbalanced_summary_df[col_names[4]] = unbalanced_f1score
unbalanced_summary_df[col_names[5]] = unbalanced_roc

# plot figures to better show the results

# it is better to save the numbers and figures for your presentation.
unbalanced_summary_df

```

	Classifier Name	Accuracy Score	Precision Score	Recall Score	F1 Score	AUROC
0	UnbalancedLogisticRegression	1.000000	1.000000	1.000000	1.000000	1.0
1	UnbalancedRandomForestClassifier	1.000000	1.000000	1.000000	1.000000	1.0
2	UnbalancedKNeighborsClassifier	0.994186	0.988406	0.994186	0.991288	0.5
3	UnbalancedSupportVectorClassifier	1.000000	1.000000	1.000000	1.000000	1.0
4	UnbalancedMLPClassifier	1.000000	1.000000	1.000000	1.000000	1.0

## ▼ Balanced evaluation

```
# Iterate over the trained models to evaluate each one
for i in range(len(estimators)):
    with open(balanced_models[i], 'rb') as file:
        downloaded_model = pickle.load(file)
    clf_name, _ = estimators[i]
    y_pred = downloaded_model.predict(X_test) # Predict the test set outcomes

# Calculate the AUROC score and append it to the roc list
roc.append(roc_auc_score(y_test, y_pred, average=None))

# Append classifier name to the est_name list
est_name.append(clf_name)

# Calculate and append accuracy to the est_acc list
est_acc.append(accuracy_score(y_test, y_pred))

# Calculate precision, recall, and F1 scores and append them to their respective lists
scores = precision_recall_fscore_support(y_test, y_pred, average="weighted")
print(scores)
precision_score.append(scores[0])
recall_score.append(scores[1])
f1score.append(scores[2])

# Append the confusion matrix for each classifier to the est_conf_matrix list
est_conf_matrix.append(confusion_matrix(y_test, y_pred))

# Populate the summary DataFrame with the collected metrics for each classifier
summary_df[col_names[0]] = est_name
summary_df[col_names[1]] = est_acc
summary_df[col_names[2]] = precision_score
summary_df[col_names[3]] = recall_score
summary_df[col_names[4]] = f1score
summary_df[col_names[5]] = roc

# plot figures to better show the results

# it is better to save the numbers and figures for your presentation.
summary_df
```

```
(1.0, 1.0, 1.0, None)
(0.9970421810699589, 0.9970238095238095, 0.997024152746606, None)
(0.9642001915708812, 0.9613095238095238, 0.961313979066094, None)
(0.9970421810699589, 0.9970238095238095, 0.997024152746606, None)
(0.9970421810699589, 0.9970238095238095, 0.997024152746606, None)
```

Classifier Name	Accuracy Score	Precision Score	Recall Score	F1 Score	AUROC
0 LogisticRegression	1.000000	1.000000	1.000000	1.000000	1.000000
1 RandomForestClassifier	0.997024	0.997042	0.997024	0.997024	0.997143
2 KNeighborsClassifier	0.961310	0.964200	0.961310	0.961314	0.962857
3 SupportVectorClassifier	0.997024	0.997042	0.997024	0.997024	0.997143
4 MLPClassifier	0.997024	0.997042	0.997024	0.997024	0.997143

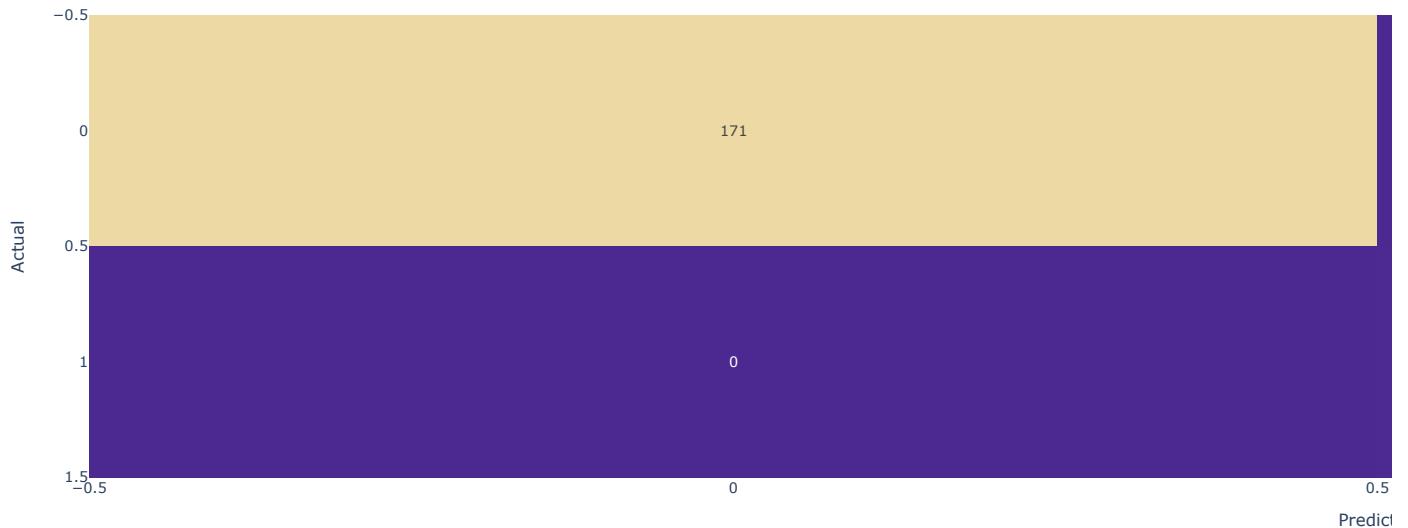
## Model comparison

```
# compare your model with others
# you don't need to re-run all other experiments, instead, you can directly refer the metrics/numbers in the paper
```

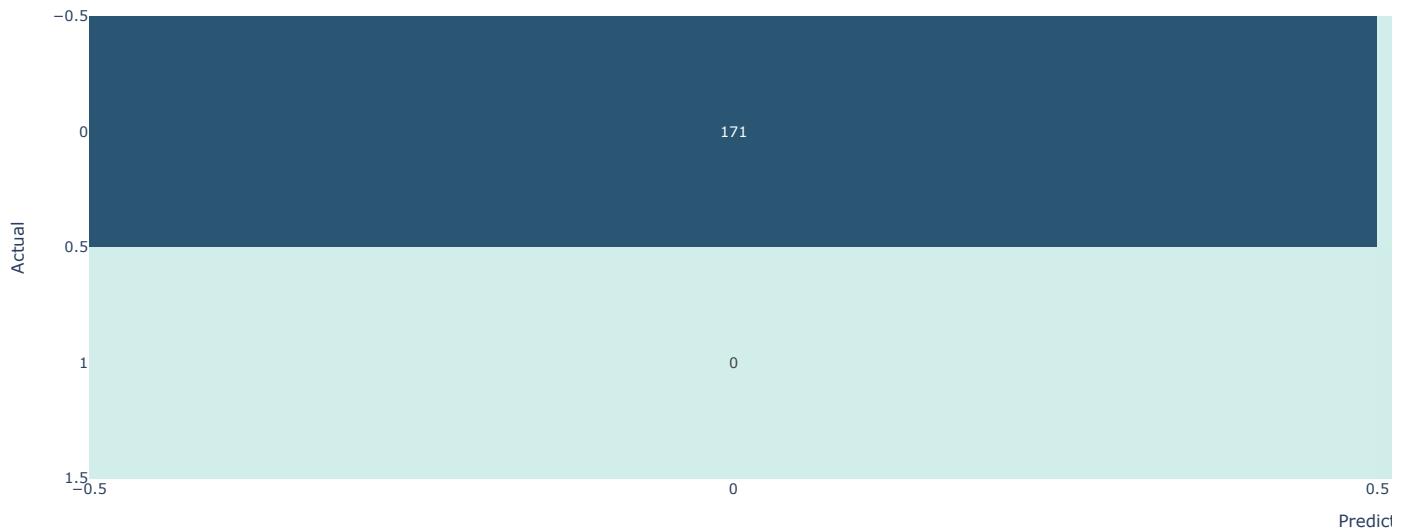
## Unbalanced comparison

```
color_scales = ["agsunset", "teal", "purp", "viridis", "viridis"]
for i in range(0, len(unbalanced_est_conf_matrix)):
    unbalanced_heatmap = px.imshow(unbalanced_est_conf_matrix[i], aspect="auto",
                                    text_auto=True,
                                    color_continuous_scale=color_scales[i])
    unbalanced_heatmap.update_layout(title=unbalanced_est_name[i])
    unbalanced_heatmap.update_xaxes(title="Predicted")
    unbalanced_heatmap.update_yaxes(title="Actual")
    unbalanced_heatmap.show()
```

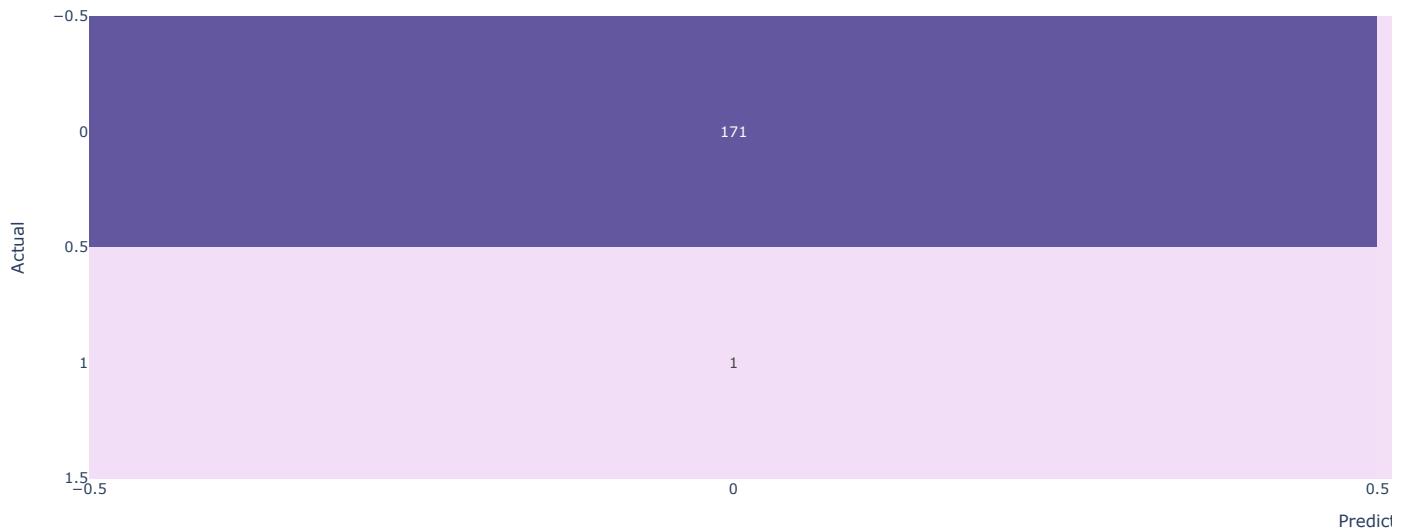
UnbalancedLogisticRegression



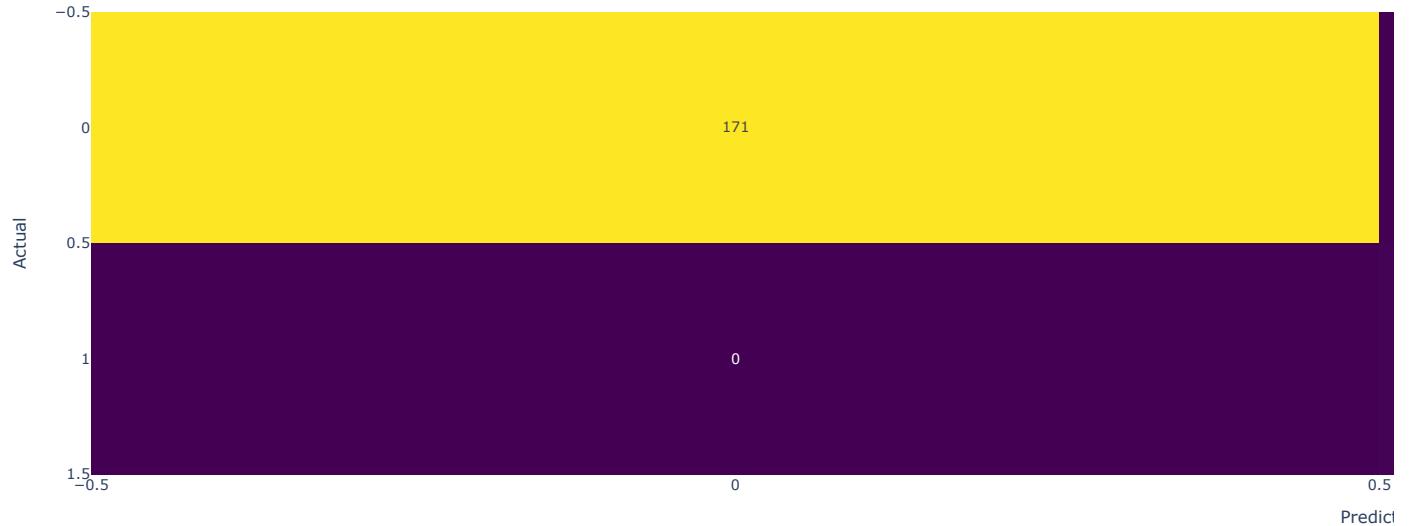
UnbalancedRandomForestClassifier



UnbalancedKNeighborsClassifier



UnbalancedSupportVectorClassifier



```
#https://plotly.com/python/error-bars/
#https://problemsolvingwithpython.com/06-Plotting-with-Matplotlib/06.07-Error-Bars/
unbalanced_acc_comparison = px.bar(unbalanced_summary_df, x="Classifier Name",
                                    y=col_names[1:len(col_names)], labels={"value":"Test Accuracy", "variable":"Metrics"}, text_auto=True,
                                    color_discrete_sequence=["deeppink",
                                                               "deepskyblue",
                                                               "darkviolet",
                                                               "darkorange",
                                                               "darkred"],
                                    barmode="group"
                                    #,error_y=[dict(type='data', array=[0.5, 1, 2], visible=True), dict(type='data', array=[0.5, 1, 2]), dict(type='data',
                                    #,error_y_minus = [dict(type='data', array=[0.5, 1, 2, 2, 1], visible=True), dict(type='data', array=[0.5, 1, 2]), dict(
                                    )
                                    unbalanced_acc_comparison.update_layout({'plot_bgcolor': 'rgba(0, 0, 0, 0)',
                                    'paper_bgcolor': 'rgba(0, 0, 0, 0)'
                                    })
                                    unbalanced_acc_comparison.show()
```

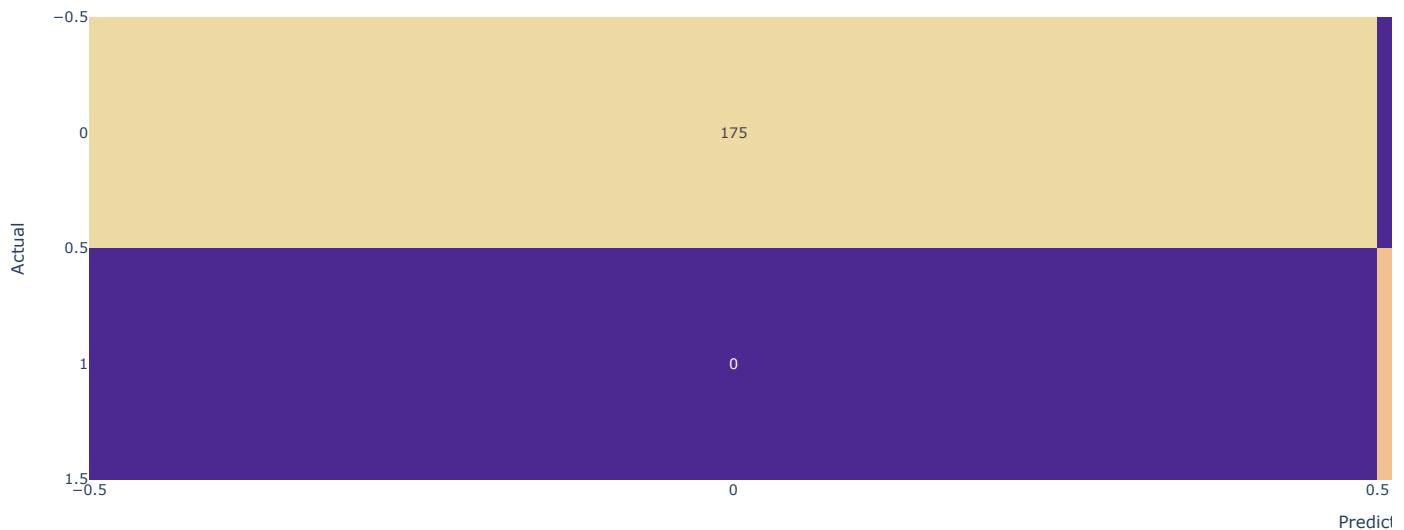


## ❖ Balanced comparison

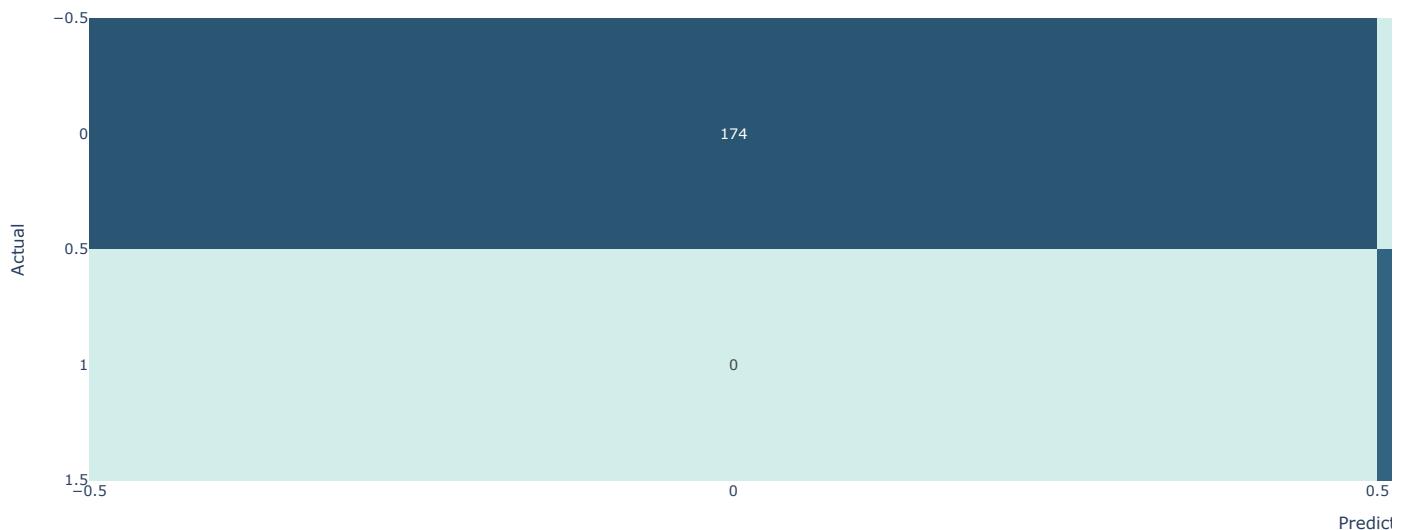
Summary with heat map

```
color_scales = ["agsunset","teal","purn","viridis","viridis"]
for i in range(0,len(est_conf_matrix)):
    heatmap = px.imshow(est_conf_matrix[i],aspect="auto",
                         text_auto=True,
                         color_continuous_scale=color_scales[i])
    heatmap.update_layout(title = est_name[i])
    heatmap.update_xaxes(title="Predicted")
    heatmap.update_yaxes(title="Actual")
    heatmap.show()
```

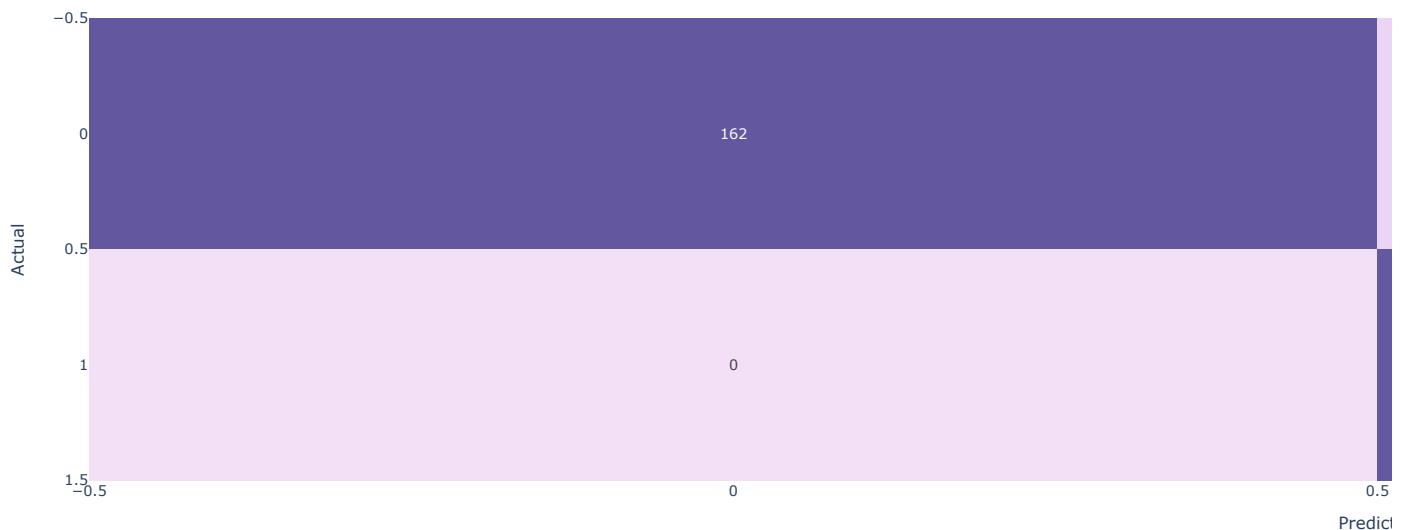
LogisticRegression



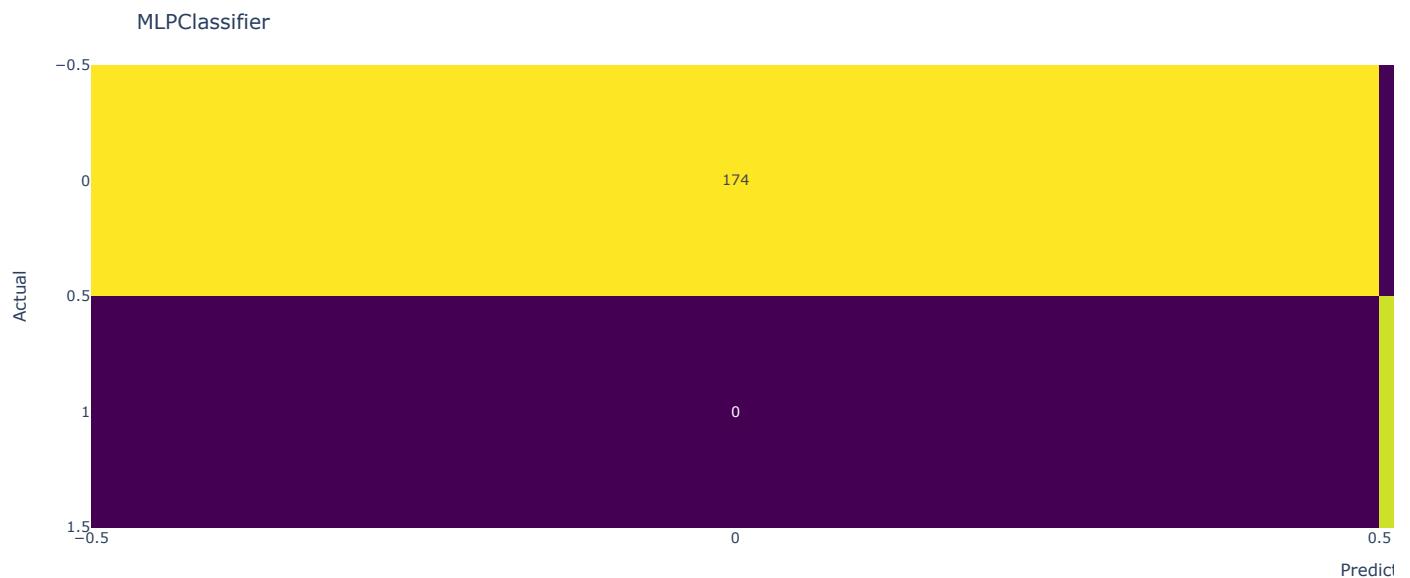
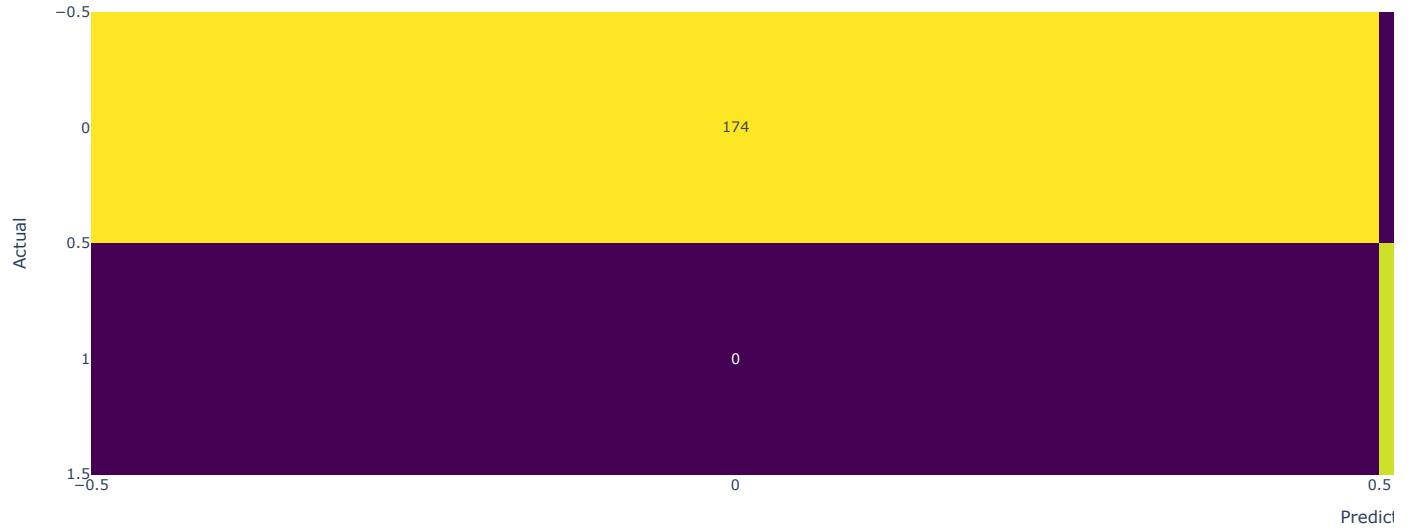
RandomForestClassifier



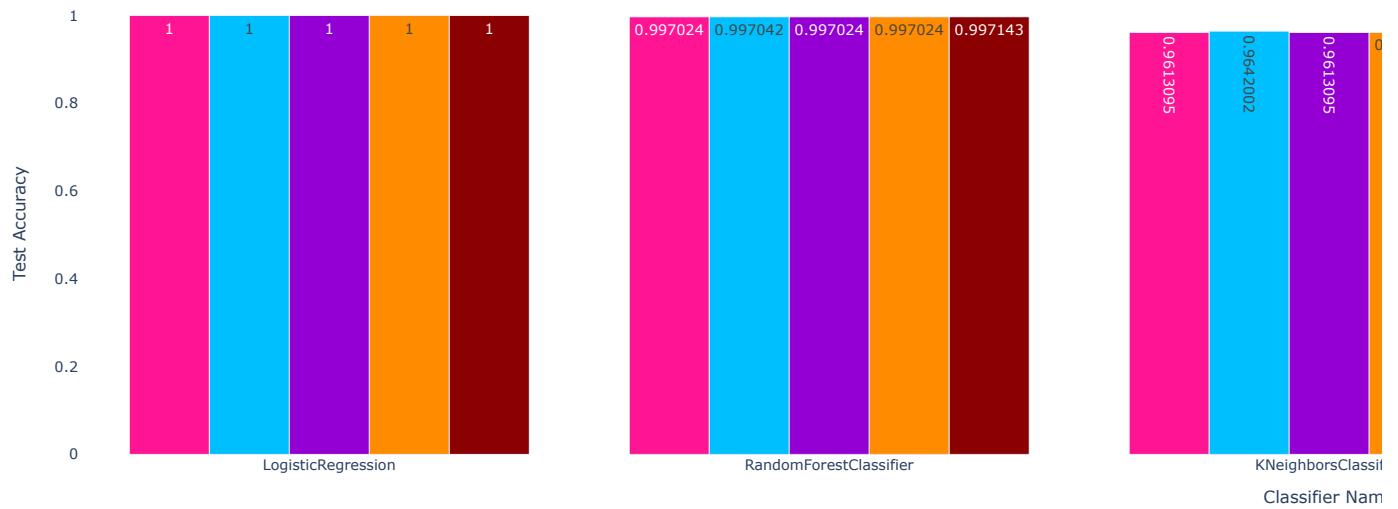
KNeighborsClassifier



SupportVectorClassifier



```
#https://plotly.com/python/error-bars/
#https://problemsolvingwithpython.com/06-Plotting-with-Matplotlib/06.07-Error-Bars/
acc_comparison = px.bar(summary_df, x="Classifier Name",
                         y=col_names[1:len(col_names)], labels={"value":"Test Accuracy", "variable":"Metrics"}, text_auto=True,
                         color_discrete_sequence=["deeppink",
                                                 "deepskyblue",
                                                 "darkviolet",
                                                 "darkorange",
                                                 "darkred"],
                         barmode="group"
                         #,error_y=[dict(type='data', array=[0.5, 1, 2],visible=True), dict(type='data', array=[0.5, 1, 2]), dict(type='data',
                         #,error_y_minus = [dict(type='data', array=[0.5, 1, 2, 2, 1],visible=True), dict(type='data', array=[0.5, 1, 2]), dict
                         )]
                         )
acc_comparison.update_layout({'plot_bgcolor': 'rgba(0, 0, 0, 0)',
                             'paper_bgcolor': 'rgba(0, 0, 0, 0)'})
acc_comparison.show()
```



#### \*\* Description of Metrics\*\*

TP: True Positive, these are the values that are positive and were predicted positive

FP: False Positive, The values which are negative but were wrongly predicted as positive

TN: True Negative, these are the values that are negative and were predicted negative

FN: False Negative, The values which are positive but were wrongly predicted as negative Precision

Precision =  $\frac{TP}{TP+FP}$

This metric measures the actual positive outcomes out of the total predicted positive outcomes. It attempts to identify the proportion of positive identifications that were correct. KNeighbors and SVC gave the worst precision score

In the context of diagnosing cervical cancer, this is metric would not be the most ideal to measure performance, as a negative case being labelled as a positive case is easily solved with confirmatory tests. However, one has to also consider the emotional and mental issues brought upon by being diagnosed with cervical cancer, as this can have a lingering effect even after having confirmatory tests. These tests should be done as soon as possible, as there may be another underlying illness that brought them to see a healthcare professional in the first place.

Recall

Recall =  $\frac{TP}{TP+FN}$

This metric measures the correctly positive predicted outcomes of the total number of positive outcomes. It answers the question of what proportions of actual positives were identified correctly. KNeighbors and SVC gave the worst precision score

In the context of diagnosing cervical cancer, we want to reduce the number of false negatives (Actual positive cases labelled as negative cases) as much possible. If an actual positive case is labelled as negative, this has serious consequences as the patient would go about their life without actually receiving potentially life saving treatment.

There are many reasons why a cancer can go misdiagnosed, these include:

The symptoms, especially in the early stages being mistaken for some other type of less serious illness. The actual test administered by a healthcare professional may give the wrong diagnosis. The 5-year survival rate tells you what percent of people live at least 5 years after the cancer is found. Percent means how many out of 100. The 5-year survival rate for all people with cervical cancer is 66%. Source

Survival rates also depend on the stage of cervical cancer that is diagnosed. When detected at an early stage, the 5-year survival rate for people with invasive cervical cancer is 92%. About 44% of people with cervical cancer are diagnosed at an early stage. If cervical cancer has spread to surrounding tissues or organs and/or the regional lymph nodes, the 5-year survival rate is 58%. If the cancer has spread to a distant part of the body, the 5-year survival rate is 18%.

F1 Score

F1 Score =  $\frac{2 \cdot TP}{2 \cdot TP + FP + FN}$

The F1 score is defined as the harmonic mean of precision and recall. Therefore, a high F1 score means both a high precision and recall, same for low and a medium score if one score is high and the other is low.

Accuracy Accuracy =  $\frac{TP + TN}{TP + TN + FP + FN}$

## ▼ Data Perturbations

In this section, we take the train and test sets and add

1. random noise
2. binary variable
3. continuous variable to three separate sets

at this point, risk\_factor\_df is balanced data set

```
from scipy.stats import bernoulli
risk_factor_df['VAR']=bernoulli.rvs(.5, size=risk_factor_df.shape[0])

#continuous
risk_factor_df['VAR']=np.random.normal(loc=0, scale=1, size=risk_factor_df.shape[0])
risk_factor_df.columns

Index(['Age', 'Number of sexual partners', 'First sexual intercourse',
       'Num of pregnancies', 'Smokes', 'Smokes (years)', 'Smokes (packs/year)',
       'Hormonal Contraceptives', 'Hormonal Contraceptives (years)', 'IUD',
       'IUD (years)', 'STDs', 'STDs (number)', 'STDs:condylomatosis',
       'STDs:cervical condylomatosis', 'STDs:vaginal condylomatosis',
       'STDs:vulvo-perineal condylomatosis', 'STDs:syphilis',
       'STDs:pelvic inflammatory disease', 'STDs:genital herpes',
       'STDs:molluscum contagiosum', 'STDs:AIDS', 'STDs:HIV',
       'STDs:Hepatitis B', 'STDs:HPV', 'STDs: Number of diagnosis',
       'STDs: Time since first diagnosis', 'STDs: Time since last diagnosis',
       'Dx:CIN', 'Dx:HPV', 'Dx', 'Hinselmann', 'Schiller', 'Cytology',
       'Biopsy', 'total_std', 'total_tests', 'Dx:Cancer', 'age_cat', 'VAR'],
       dtype='object')
```

Get data and model - the source code is poorly labeled here and is not clear on the "cancer.csv" file they use

We are assuming it is the balanced dataset

```
risk_factor_df.to_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/Rcancer2.csv', index=False)
#modified below to replicate above filename
risk_factor_df=pd.read_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/Rcancer2.csv')
```

risk\_factor\_df

	Age	Number of sexual partners	First sexual intercourse	Num of pregnancies	Smokes	Smokes (years)	Smokes (packs/year)	Hormonal Contraceptives	Hormonal Contraceptives (years)	IUD	...	Dx	Hinselmann	Schill
0	18	4	15	1	0	0.000000	0.000000	0	0.000000	0	...	0	0	0
1	15	1	14	1	0	0.000000	0.000000	0	0.000000	0	...	0	0	0
2	34	1	17	1	0	0.000000	0.000000	0	0.000000	0	...	0	0	0
3	52	5	16	4	1	37.000000	37.000000	1	3.000000	0	...	0	0	0
4	46	3	21	4	0	0.000000	0.000000	1	15.000000	0	...	0	0	0
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1672	30	3	18	1	0	6.667492	0.096982	1	4.818407	0	...	0	0	0
1673	30	2	18	2	0	3.836437	0.055803	0	2.092602	0	...	0	0	0
1674	31	2	18	1	0	9.827477	0.142945	1	6.319779	0	...	0	0	0
1675	31	2	18	1	0	3.763702	0.054745	1	7.973536	0	...	0	0	0
1676	27	2	14	2	0	0.006449	0.000094	1	1.002931	0	...	0	0	0

## ✓ Checkpoint: Get Original

```
# X_test=pd.read_csv(gdown.download('https://drive.google.com/file/d/1ggTvbeS9kerpVVAZGXP1gulvyqC8lH4S/view?usp=share_link', format='csv', fuz
X_test = pd.read_csv(root+'/X_test.csv')
X_test.drop('Unnamed: 0', inplace=True, axis=1)
# y_test=pd.read_csv(gdown.download('https://drive.google.com/file/d/1WsUWr09Nwpd6K_fRZGtwsKSJdczVNx0/view?usp=share_link', format='csv', fuz
y_test = pd.read_csv(root+'/y_test.csv')
y_test.drop('Unnamed: 0', inplace=True, axis=1)
# X_train=pd.read_csv(gdown.download('https://drive.google.com/file/d/10nCY70gXQbT32MSiGNKivYVH8QQFpCAx/view?usp=share_link', format='csv', fu
X_train = pd.read_csv(root+'/X_train.csv')
X_train.drop('Unnamed: 0', inplace=True, axis=1)
# y_train=pd.read_csv(gdown.download('https://drive.google.com/file/d/1C5euZUKZ6GLeLA3Z-lPienKAxMmFKtpi/view?usp=share_link', format='csv', fu
y_train = pd.read_csv(root+'/y_train.csv')
y_train.drop('Unnamed: 0', inplace=True, axis=1)
```

len(X\_test)

336

## Normal

```
from scipy.stats import bernoulli

# Adding a new binary variable 'VARB' to the test dataset, with each value independently drawn
# from a Bernoulli distribution where the probability of a 1 is 0.5 (i.e., a fair coin toss).
X_test['VARB'] = bernoulli.rvs(0.5, size=X_test.shape[0])

# Similarly, adding the 'VARB' binary variable to the training dataset.
X_train['VARB'] = bernoulli.rvs(0.5, size=X_train.shape[0])

# Adding another binary variable 'VARC' to the test dataset, with values drawn
# from the same distribution as 'VARB'.
X_test['VARC'] = bernoulli.rvs(0.5, size=X_test.shape[0])

# Adding 'VARC' to the training dataset as well.
X_train['VARC'] = bernoulli.rvs(0.5, size=X_train.shape[0])
```

X\_test

```
# Loop over each column in the testing dataset
for col in X_test.columns:
    # Add Gaussian noise to each value in the current column of the testing dataset
    # Noise is centered at 0 with a standard deviation of 0.1
    X_test[col] += np.random.normal(loc=0, scale=.1, size=X_test.shape[0])

    # Add Gaussian noise to each value in the current column of the training dataset
    # Noise is also centered at 0 with a standard deviation of 0.1
    X_train[col] += np.random.normal(loc=0, scale=.1, size=X_train.shape[0])
```

X\_test

	Age	Number of sexual partners	First sexual intercourse	Num of pregnancies	Smokes	Smokes (years)	Smokes (packs/year)	Hormonal Contraceptives	Hormonal Contraceptives (years)	IUD	...	STDs: Time since last diagnosis
0	26.895518	4.974920	18.035834	1.978488	0.029813	0.217016	0.052782	-0.277206	2.492050	0.098544	...	2.987768 -
1	34.954572	2.823628	18.106521	2.184741	0.011828	0.004689	0.141550	0.934624	0.556029	1.002716	...	3.159224 -
2	31.972781	2.231742	18.015258	1.981678	-0.085296	-0.025531	-0.041226	1.102458	1.901299	1.103283	...	3.078869
3	27.011809	2.024805	19.138994	1.901063	0.071766	0.095571	-0.062101	0.986939	6.840066	-0.042134	...	2.790036 -
4	41.002527	3.012424	16.039087	2.023518	0.991945	4.971395	2.488914	-0.146365	-0.099397	-0.122486	...	2.968105
...	...	...	...	...	...	...	...	...	...	...	...	...
331	29.026820	2.026303	16.840819	2.009832	-0.021567	0.110689	-0.026657	1.052006	9.213151	0.075738	...	3.151456
332	31.076680	2.922342	16.181364	4.004974	0.872608	10.002096	1.118925	-0.147803	-0.165106	0.063586	...	2.992484 -
333	16.053972	2.077780	15.129517	1.008182	0.062453	0.197460	-0.115974	-0.059276	-0.044065	-0.022757	...	2.987023 -
334	27.017067	4.076471	16.957965	1.892029	-0.173906	-0.036719	-0.081512	0.909618	2.543739	0.092825	...	3.046150
335	26.875555	5.139867	17.993302	2.235003	0.107602	-0.052850	0.113064	0.086839	2.030001	-0.000458	...	2.949293

Save state from random noise

```
X_test.to_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/Noise_X_test.csv')
y_test.to_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/Noise_y_test.csv')
X_train.to_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/Noise_X_train.csv')
y_train.to_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/Noise_y_train.csv')
```

#### ✓ Checkpoint: Get Normal

```
# Noise_X_test=pd.read_csv(gdown.download('https://drive.google.com/file/d/1erD_zgcVreaBvxZpiB57hYl2JaIwHFJ9/view?usp=share_link', format='csv')
Noise_X_test = pd.read_csv(root+'/Noise_X_test.csv')
Noise_X_test.drop('Unnamed: 0', inplace=True, axis=1)
# Noise_y_test=pd.read_csv(gdown.download('https://drive.google.com/file/d/1cNtkdYaPYlw4HXiM70A-npcPPIGWDJ_R/view?usp=share_link', format='csv')
Noise_y_test = pd.read_csv(root+'/Noise_y_test.csv')
Noise_y_test.drop('Unnamed: 0', inplace=True, axis=1)
# Noise_X_train=pd.read_csv(gdown.download('https://drive.google.com/file/d/13SUdzZG8_TxTr3sSfwPKT0zyjvqYDK3s/view?usp=share_link', format='cs
Noise_X_train = pd.read_csv(root+'/Noise_X_train.csv')
Noise_X_train.drop('Unnamed: 0', inplace=True, axis=1)
Noise_y_train = pd.read_csv(root+'/Noise_y_train.csv')
# Noise_y_train=pd.read_csv(gdown.download('https://drive.google.com/file/d/1rVKdQaBTxyvFMWbYsh_HTFyk7yH9IznS/view?usp=share_link', format='cs
Noise_y_train.drop('Unnamed: 0', inplace=True, axis=1)
```

Noise\_X\_test

#### ✓ Binary

```
#binary
X_test=pd.read_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/X_test.csv')
X_test.drop('Unnamed: 0', inplace=True, axis=1)
y_test=pd.read_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/y_test.csv')
y_test.drop('Unnamed: 0', inplace=True, axis=1)
X_train=pd.read_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/X_train.csv')
X_train.drop('Unnamed: 0', inplace=True, axis=1)
y_train=pd.read_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/y_train.csv')
y_train.drop('Unnamed: 0', inplace=True, axis=1)

# no random noise
from scipy.stats import bernoulli

X_test['VAR']=bernoulli.rvs(.5, size=X_test.shape[0])
X_train['VAR']=bernoulli.rvs(.5, size=X_train.shape[0])

X_test.to_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/Binary_X_test.csv')
y_test.to_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/Binary_y_test.csv')
X_train.to_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/Binary_X_train.csv')
y_train.to_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/Binary_y_train.csv')
```

#### ✓ Checkpoint: Get Binary

```
#binary
# X_test=pd.read_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/X_test.csv')
Binary_X_test = pd.read_csv(root+'/Binary_X_test.csv')
Binary_X_test.drop('Unnamed: 0', inplace=True, axis=1)
# y_test=pd.read_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/y_test.csv')
Binary_y_test = pd.read_csv(root+'/Binary_y_test.csv')
Binary_y_test.drop('Unnamed: 0', inplace=True, axis=1)
# X_train=pd.read_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/X_train.csv')
Binary_X_train = pd.read_csv(root+'/Binary_X_train.csv')
Binary_X_train.drop('Unnamed: 0', inplace=True, axis=1)
Binary_y_train = pd.read_csv(root+'/Binary_y_train.csv')
# y_train=pd.read_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/y_train.csv')
Binary_y_train.drop('Unnamed: 0', inplace=True, axis=1)
```

Binary\_X\_train

Age	Number of sexual partners	First sexual intercourse	Num of pregnancies	Smokes	Smokes (years)	Smokes (packs/year)	Hormonal Contraceptives	Hormonal Contraceptives (years)	IUD	...	STDs: Time since first diagnosis	STDs: Time since last diagnosis	
											...	...	
0	22	1	19	1	0	0.000000	0.000000	1	0.500000	0	...	4.0	3.0
1	30	2	13	3	1	22.000000	3.300000	0	0.000000	0	...	3.0	3.0
2	30	2	18	2	0	0.000000	0.000000	0	0.045529	0	...	4.0	3.0
3	18	1	15	2	0	0.000000	0.000000	1	0.080000	0	...	4.0	3.0
4	51	4	16	4	0	34.031351	34.031351	1	2.839533	0	...	4.0	3.0
...	...	...	...	...	...	...	...	...	...	...	...	...	...
1336	33	1	17	3	0	0.000000	0.000000	1	0.160000	1	...	4.0	3.0
1337	38	1	16	3	0	0.000000	0.000000	1	15.600997	0	...	4.0	3.0
1338	17	2	15	2	0	0.000000	0.000000	1	0.160000	0	...	4.0	3.0
1339	21	4	14	1	0	0.000000	0.000000	1	0.500000	0	...	4.0	3.0
1340	27	4	19	2	0	0.000000	0.000000	1	4.144126	0	...	4.0	3.0

## ▼ Continuous

#continuous

```
# X_test=pd.read_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/X_test.csv')
X_test.drop('Unnamed: 0', inplace=True, axis=1)
# y_test=pd.read_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/y_test.csv')
y_test.drop('Unnamed: 0', inplace=True, axis=1)
# X_train=pd.read_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/X_train.csv')
X_train.drop('Unnamed: 0', inplace=True, axis=1)
# y_train=pd.read_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/y_train.csv')
y_train.drop('Unnamed: 0', inplace=True, axis=1)

X_test['VAR']=np.random.normal(loc=0, scale=1, size=X_test.shape[0])
X_train['VAR']=np.random.normal(loc=0, scale=1, size=X_train.shape[0])
```

```
X_test.to_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/Continuous_X_test.csv')
y_test.to_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/Continuous_y_test.csv')
X_train.to_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/Continuous_X_train.csv')
y_train.to_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/Continuous_y_train.csv')
```

## ▼ Checkpoint: Get Continuous

```
#Continuous
# X_test=pd.read_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/X_test.csv')
Continuous_X_test = pd.read_csv(root+'/Continuous_X_test.csv')
Continuous_X_test.drop('Unnamed: 0', inplace=True, axis=1)
# y_test=pd.read_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/y_test.csv')
Continuous_y_test = pd.read_csv(root+'/Continuous_y_test.csv')
Continuous_y_test.drop('Unnamed: 0', inplace=True, axis=1)
# X_train=pd.read_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/X_train.csv')
Continuous_X_train = pd.read_csv(root+'/Continuous_X_train.csv')
Continuous_X_train.drop('Unnamed: 0', inplace=True, axis=1)
Continuous_y_train = pd.read_csv(root+'/Continuous_y_train.csv')
# y_train=pd.read_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/y_train.csv')
Continuous_y_train.drop('Unnamed: 0', inplace=True, axis=1)
```

Continuous\_X\_test

	Age	Number of sexual partners	First sexual intercourse	Num of pregnancies	Smokes	Smokes (years)	Smokes (packs/year)	Hormonal Contraceptives	Hormonal Contraceptives (years)	IUD	...	STDs: Time since first diagnosis	STDs: Time since last diagnosis
0	27	5	18	2	0	0.0	0.0	0	2.635890	0	...	4.0	3.0
1	35	3	18	2	0	0.0	0.0	1	0.464403	1	...	4.0	3.0
2	32	2	18	2	0	0.0	0.0	1	2.000000	1	...	4.0	3.0
3	27	2	19	2	0	0.0	0.0	1	7.000000	0	...	4.0	3.0
4	41	3	16	2	1	5.0	2.5	0	0.000000	0	...	4.0	3.0
...	...	...	...	...	...	...	...	...	...	...	...	...	...
331	29	2	17	2	0	0.0	0.0	1	9.000000	0	...	4.0	3.0
332	31	3	16	4	1	10.0	1.0	0	0.000000	0	...	4.0	3.0
333	16	2	15	1	0	0.0	0.0	0	0.000000	0	...	4.0	3.0
334	27	4	17	2	0	0.0	0.0	1	2.593075	0	...	4.0	3.0
335	27	5	18	2	0	0.0	0.0	0	2.187766	0	...	4.0	3.0

## ✓ Checkpoint: Set rnd\_clf Models

Fit on the continuous perturbation from the previous section

```
rnd_clf = RandomForestClassifier()
rnd_clf.fit(X_train, y_train)
noise_rnd_clf = RandomForestClassifier()
noise_rnd_clf.fit(Noise_X_train, Noise_y_train)
binary_rnd_clf = RandomForestClassifier()
binary_rnd_clf.fit(Binary_X_train, Binary_y_train)
continuous_rnd_clf = RandomForestClassifier()
continuous_rnd_clf.fit(Continuous_X_train, Continuous_y_train)
```

```
▼ RandomForestClassifier
RandomForestClassifier()
```

```
model=rnd_clf
noise_model = noise_rnd_clf
binary_model = binary_rnd_clf
continuous_model = continuous_rnd_clf
```

## ✓ Local Methods

SAVE THE DATA SO THIS IS NOT A CHECKPOINT

We generated feature importance explanations using LIME, three variants of SHAP (Tree-SHAP (TSHAP), Kernel-SHAP (KSHAP) and Sampling-SHAP (SSHAP)), Tree Interpreter, DICE and Local Surrogates.

LIME is a model-agnostic technique for explaining the predictions of machine learning models on a local, instance-specific basis. LIME approximates the predictions of  $f(x)$  by with a simpler  $g(x)$  for an instance of interest  $x$ .

SHAP values explain the output of any machine learning model by attributing a value to each feature for a prediction based on their contributions towards that prediction. This is done by considering all possible feature combinations. There are many variants of KSHAP.

DICE is a model-agnostic method for generating diverse and interpretable counterfactual explanations for individual predictions. DICE finds instances similar to original instance  $x$ , but with different predicted outcomes. Optimization requires minimizing a distance metric between the counterfactuals and  $x$ , subject to constraints that ensure dissimilarity among generated counterfactuals. Counterfactuals are generated by perturbing the features of  $x$  while staying within the feasible range of feature values.

Tree Interpreter is a model-specific method for interpreting predictions of tree-based models, such as random forests. It provides a way to attribute feature importance values for predictions made by tree-based models, by tracing the decision path of an instance through the tree and measuring the contribution of each feature towards the prediction. This is done by summing the changes in prediction associated with each decision node along the path, weighted by the proportion of instances that pass through each decision node.

Local Surrogates (Molnar, 2022) are model-specific methods for interpreting predictions of machine learning models that aim to provide insights into the decision-making process of the black-box model for a specific prediction, by fitting a simpler model, such as linear regression

or decision tree, using the training data in the local neighborhood of the instance of interest. Local surrogates generate explanations in the form of interpretable models or feature importance values, depending on the specific method used.

Source: [1] Ayad, W., Bonnier, T., Bosch, B., Read, J., & Parbhoo, S. (2023). Which Explanation Makes Sense? A Critical Evaluation of Local Explanations for Assessing Cervical Cancer Risk Factors. Ecole polytechnique, 1-50.

✓ Initialize function

```

def run_explainers(mode, model, X_train, X_test, y_train, y_test):
    # Initialize various SHAP explainers and a DataFrame to hold zero-initialized contributions for each feature.
    # This DataFrame uses the same structure and column names as X_test.
    GloSur = kernelSHAP = treeSHAP = samplingSHAP = limecontrib = ticontrib = dicecontrib = \
        pd.DataFrame([[0.0] * X_test.shape[1]] * X_test.shape[0], columns=X_test.columns)

    # Initialize dictionaries to store feature importances from different explainers.
    fi_1 = fi_2 = fi_3 = fi_4 = fi_5 = fi_6 = fi_7 = {f'{x}': 0.0 for x in X_test.columns}

    # Initialize a dictionary to store results temporarily.
    res = dict()

    # Retrieve the list of feature names from the test dataset.
    features = X_test.columns

    ## GloSur

    # Print a header for the GloSur results section.
    print("-GLOSUR-")

    # Set up the GloSur explainer using a linear model as the surrogate to approximate the neural network's behavior.
    explainer = MimicExplainer(model,
                                X_train,
                                LinearExplainableModel,
                                augment_data=False, # Do not augment data; use the original dataset.
                                features=features, # List of features to explain.
                                model_task="classification") # Task type (classification).

    # Generate global explanations based on the entire test dataset.
    global_explanation = explainer.explain_global(X_test)

    # Extract local importance values for each instance and convert them into a DataFrame.
    temp = pd.DataFrame(global_explanation.local_importance_values[1], columns=features)

    # Update the GloSur DataFrame with new importance values, adding to existing values.
    GloSur = GloSur.add(temp, fill_value=0)

    # Reset the results dictionary and retrieve feature importance as a dictionary from the global explanation.
    res = dict()
    res = global_explanation.get_feature_importance_dict()

    # Update fi_1 dictionary with aggregated feature importances, combining existing values with new ones.
    fi_1 = {k: fi_1.get(k, 0) + res.get(k, 0) for k in set(fi_1)}
    fi_1
    ## KSHAP

    # We had to use kmeans to summarize. the full data would have taken hours
    # Setting a smaller K to be able to train

    print("-KSHAP-")
    # KSHAP
    K = 10 # Adjust. 1341 is too big

    # Step 1: Summarize the background data
    X_train_summary = shap.kmeans(X_train, K)

    # Step 2: Create the explainer
    explainer = shap.KernelExplainer(model.predict_proba, X_train_summary, feature_perturbation='interventional')

    # Step 3: Calculate SHAP values
    shap_values = explainer.shap_values(X_test)

    # Convert SHAP values to DataFrame for easier manipulation (assuming binary classification)
    temp = pd.DataFrame(shap_values[1], columns=features)

    kernelSHAP = kernelSHAP.add(temp, fill_value=0)

    # Step 5: Compute Feature Importance
    res = {feature: np.mean(np.abs(kernelSHAP[feature])) for feature in kernelSHAP.columns}

    # Update or initialize feature importances
    fi_2 = {k: fi_2.get(k, 0) + res.get(k, 0) for k in set(fi_2)}
    fi_2
    ## TShap

    print("-TSHAP-")
    # TSHAP TODO acction check_additivity=False
    explainer = shap.TreeExplainer(model, X_train, check_additivity=False)
    shap_values = explainer.shap_values(X_test)

    temp=pd.DataFrame(shap_values[1], columns=features)
    treeSHAP=treeSHAP.add(temp, fill_value=0)

    res = dict()

```



```

for i in list(treeSHAP.columns):
    res[i]=np.mean(np.abs(treeSHAP[i]))
fi_3={k: fi_3.get(k, 0) + res.get(k, 0) for k in set(fi_3)}
fi_3
## SSHAP
print("-SSHAP-")
# Reduce the number of samples used for explanations
X_train_sampled = shap.sample(X_train, 20) # for example, sample 20 instances

# Create the SamplingExplainer using the sampled training data
explainer = shap.explainers.Sampling(model.predict_proba, X_train_sampled)
shap_values = explainer.shap_values(X_test)
temp = pd.DataFrame(shap_values[1], columns=features)
samplingSHAP = samplingSHAP.add(temp, fill_value=0)

# Aggregate and compute feature importance
res = {feature: np.mean(np.abs(samplingSHAP[feature])) for feature in samplingSHAP.columns}
fi_4 = {k: fi_4.get(k, 0) + res.get(k, 0) for k in set(fi_4)}
fi_4
## LIME
print("-LIME-")

# LIME
explainer = lime.lime_tabular.LimeTabularExplainer(X_train.values, mode='classification', feature_names=X_test.columns)

all=[]
for i in range (len(X_test)):
    exp = explainer.explain_instance(X_test.iloc[i], model.predict_proba, num_features=X_test.shape[1])
    all.append(sorted(exp.as_map()[1]))

all_res=[]
for i in range(len(all)):
    res = dict()
    for j in range(len(all[0])):
        res[features[j]] = all[i][j][1]
    all_res.append(res)

temp=pd.DataFrame(all_res, columns=features)
limecontrib=limecontrib.add(temp, fill_value=0)

res = dict()
for j in list(limecontrib.columns):
    res[j]=np.mean(np.abs(limecontrib[j]))
fi_5={k: fi_5.get(k, 0) + res.get(k, 0) for k in set(fi_5)}
fi_5
## Tree Interpreter
# Random forest classifier is not correct model type.
# Base learner needs to be a DecisionTreeClassifier or DecisionTreeRegressor.
# Average out the trees in the estimators
# Prepare containers for the individual tree results
all_contributions = []
all_biases = []

# Iterate over each tree in the RandomForest
for tree in model.estimators_:
    prediction, bias, contributions = ti.predict(tree, X_test)
    all_biases.append(bias)
    all_contributions.append(contributions)

# Convert the lists into numpy arrays for easier mean calculation
all_contributions = np.array(all_contributions)
all_biases = np.array(all_biases)

# Calculate the mean contributions and biases across all trees
mean_contributions = np.mean(all_contributions, axis=0)
mean_biases = np.mean(all_biases, axis=0)

# Organize contributions into a DataFrame
all_res = []
for i in range(len(mean_contributions)):
    res = dict()
    for j in range(len(features)):
        res[features[j]] = mean_contributions[i, j, 1] # Index 1 for contributions
    all_res.append(res)

temp = pd.DataFrame(all_res, columns=features)
ticontrib = temp.sum()

# Calculate the mean of absolute values of contributions for each feature
res = {feature: np.mean(np.abs(ticontrib[feature])) for feature in ticontrib.index}
fi_6 = {k: fi_6.get(k, 0) + res.get(k, 0) for k in set(fi_6)}
fi_6
## DICE
# df.select_dtypes(exclude=int)
label = "Dx:Cancer"

```



```

temp1=X_train
temp1['Dx:Cancer']=y_train
temp2=X_test
temp2['Dx:Cancer']=y_test

temp3=pd.concat([temp1,temp2])

risk_factor_df=temp3
#debugging
# print(risk_factor_df.columns==X_test.columns)
# print(risk_factor_df.columns)
# X_test.columns
# print('df dtypes:', risk_factor_df.dtypes)
# print('X_test dtypes: ', X_test.dtypes)

print("-DICE-")
import dice_ml
df=risk_factor_df

# print("Label (outcome name):", label)
# print("Is label in DataFrame columns?", label in df.columns)

# print(df.columns == X_test.columns)
cont_features = list(df.columns)
cont_features.remove(label)

# Sample a fraction of the data
# Gaussian Noise took way too long
frac = .1
total_CFS=10
if mode == 'Noise':
    frac = .02
    total_CFS=5
sampled_df = df.sample(frac=frac, random_state=42) # Ensure reproducibility

# Continue with the sampled DataFrame
d = dice_ml.Data(dataframe=sampled_df, continuous_features=cont_features, outcome_name=label)
m = dice_ml.Model(model=model, backend="sklearn")
exp = dice_ml.Dice(d, m, method="random")

#modification to remove label
# query_instance = X_test
query_instance = X_test.drop(columns=[label])
e1 = exp.generate_counterfactuals(query_instance, total_CFs=total_CFS, desired_range=None,
                                    desired_class="opposite",
                                    permitted_range=None, features_to_vary="all")

imp = exp.local_feature_importance(query_instance, posthoc_sparsity_param=None)
dicecontrib=pd.DataFrame.from_dict(imp.local_importance)

res = dict()
for j in list(dicecontrib.columns):
    res[j]=np.mean(np.abs(dicecontrib[j]))
fi_7={k: fi_7.get(k, 0) + res.get(k, 0) for k in set(fi_7)}
fi_7

GloSur.to_csv(f"/content/drive/My Drive/DL4H_Sp24_Final_Project/{mode}_glosur.csv", index=False)
kernelSHAP.to_csv(f"/content/drive/My Drive/DL4H_Sp24_Final_Project/{mode}_Kshap.csv", index=False)
treeSHAP.to_csv(f"/content/drive/My Drive/DL4H_Sp24_Final_Project/{mode}_Tshap.csv", index=False)
samplingSHAP.to_csv(f"/content/drive/My Drive/DL4H_Sp24_Final_Project/{mode}_Sshap.csv", index=False)
limecontrib.to_csv(f"/content/drive/My Drive/DL4H_Sp24_Final_Project/{mode}_lime.csv", index=False)
ticontrib.to_csv(f"/content/drive/My Drive/DL4H_Sp24_Final_Project/{mode}_ti.csv", index=False)
dicecontrib.to_csv(f"/content/drive/My Drive/DL4H_Sp24_Final_Project/{mode}_dice.csv", index=False)

dics = []

fi_1['Method'] = 'Surrogates'
dics.append(fi_1)
fi_2['Method'] = 'KSHAP'
dics.append(fi_2)
fi_3['Method'] = 'TSHAP'
dics.append(fi_3)
fi_4['Method'] = 'SSHAP'
dics.append(fi_4)
fi_5['Method'] = 'LIME'
dics.append(fi_5)
fi_6['Method'] = 'TI'
dics.append(fi_6)
fi_7['Method'] = 'DICE'
dics.append(fi_7)

dics = pd.DataFrame(dics)
methods=dics['Method']
dics['Method']=methods

```

```
dics.to_csv(f"/content/drive/My Drive/DL4H_Sp24_Final_Project/{mode}_localExplainMethods.csv", index=False)
print(mode, " is complete!")

def run_explainers_ti(mode, model, X_train, X_test, y_train, y_test):
    # Initialize a dictionary to store results temporarily.
    print(f'starting {mode}')
    res = dict()

    # Retrieve the list of feature names from the test dataset.
    features = X_test.columns
    # Initialize an empty DataFrame to store contributions from all trees
    all_contributions = pd.DataFrame(columns=features, index=X_test.index)
    all_contributions.fillna(0, inplace=True)
    # print(len(model.estimators_))
    # Iterate over each estimator (tree) in the random forest
    for tree in model.estimators_:
        prediction, bias, contributions = ti.predict(tree, X_test)

        # Sum up the contributions for each feature from this tree
        for i in range(len(X_test)):
            all_contributions.iloc[i] += contributions[i][:,1] # assuming contributions[i] is structured as [(bias, contribution)]

    # Now average the contributions across all trees
    average_contributions = all_contributions / len(model.estimators_)
    # Compute the mean of absolute contributions for each feature
    feature_importance = average_contributions.abs().mean()
    fi_dict = feature_importance.to_dict()
    average_contributions.to_csv(f"/content/drive/My Drive/DL4H_Sp24_Final_Project/{mode}_ti.csv", index=False)
    file_path = f"/content/drive/My Drive/DL4H_Sp24_Final_Project/{mode}_localExplainMethods.csv"

    # Load the existing data from CSV
    dics = pd.read_csv(file_path)

    # Find the index of the row where the Method is 'TI'
    ti_index = dics[dics['Method'] == 'TI'].index

    # Update the 'TI' row with the correct dictionary values
    for key in fi_dict:
        if key in dics.columns:
            dics.loc[ti_index, key] = fi_dict[key]

    # Save the updated DataFrame back to CSV
    dics.to_csv(file_path, index=False)

print(f"Updated the TI method in {file_path}")
```

## ▼ Continuous (Done)

```
run_explainers('Continuous', continuous_rnd_clf, Continuous_X_train, Continuous_X_test, Continuous_y_train, Continuous_y_test)
```

```
-----
NameError: name 'continuous_rnd_clf' is not defined
Traceback (most recent call last)
<ipython-input-150-a6e6a1c4b40b> in <cell line: 1>()
----> 1 run_explainers('Continuous', continuous_rnd_clf, Continuous_X_train, Continuous_X_test, Continuous_y_train, Continuous_y_test)

NameError: name 'continuous_rnd_clf' is not defined
```

## ▼ Original (Done)

```
run_explainers('Original', rnd_clf, X_train, X_test, y_train, y_test)
```

## ▼ Binary (Done)

```
run_explainers('Binary', binary_rnd_clf, Binary_X_train, Binary_X_test, Binary_y_train, Binary_y_test)
```

## ▼ Gaussian Noise (Done)

We had to further decrease the dice sampling for this, otherwise the training was taking too long

```
run_explainers('Noise', noise_rnd_clf, Noise_X_train, Noise_X_test, Noise_y_train, Noise_y_test)
```

## ▼ Rerun TI

```
run_explainers_ti('Original', rnd_clf, X_train, X_test, y_train, y_test)
run_explainers_ti('Continuous', continuous_rnd_clf, Continuous_X_train, Continuous_X_test, Continuous_y_train, Continuous_y_test)
run_explainers_ti('Binary', binary_rnd_clf, Binary_X_train, Binary_X_test, Binary_y_train, Binary_y_test)
run_explainers_ti('Noise', noise_rnd_clf, Noise_X_train, Noise_X_test, Noise_y_train, Noise_y_test)
```

```
starting Original
Updated the TI method in /content/drive/My Drive/DL4H_Sp24_Final_Project/Original_localExplainMethods.csv
starting Continuous
Updated the TI method in /content/drive/My Drive/DL4H_Sp24_Final_Project/Continuous_localExplainMethods.csv
starting Binary
Updated the TI method in /content/drive/My Drive/DL4H_Sp24_Final_Project/Binary_localExplainMethods.csv
starting Noise
Updated the TI method in /content/drive/My Drive/DL4H_Sp24_Final_Project/Noise_localExplainMethods.csv
```

## ▼ Evaluation

```
#get explanations
instance=291
```

### ▼ Checkpoint: Get original contributions

```
#DL
gscontrib = pd.read_csv(root+'/Original_glosur.csv')
kercontrib = pd.read_csv(root+'/Original_Kshap.csv')
samcontrib = pd.read_csv(root+'/Original_Sshap.csv')
trecontrib = pd.read_csv(root+'/Original_Tshap.csv')
limecontrib = pd.read_csv(root+'/Original_lime.csv')
ticontrib = pd.read_csv(root+'/Original_ti.csv')
dicecontrib = pd.read_csv(root+'/Original_dice.csv')
all_fi = pd.read_csv(root+'/Original_localExplainMethods.csv')
```

### ▼ Noise Contributions

```
#RF
gscontrib_noise = pd.read_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/Noise_glosur.csv')
kercontrib_noise = pd.read_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/Noise_Kshap.csv')
samcontrib_noise = pd.read_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/Noise_Sshap.csv')
trecontrib_noise = pd.read_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/Noise_Tshap.csv')
limecontrib_noise = pd.read_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/Noise_lime.csv')
ticontrib_noise = pd.read_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/Noise_ti.csv')
dicecontrib_noise = pd.read_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/Noise_dice.csv')
all_fi_noise = pd.read_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/Noise_localExplainMethods.csv')
```

### ▼ Continuous contributions

```
#VAR continue
gscontrib_continuous = pd.read_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/Continuous_glosur.csv')
kercontrib_continuous = pd.read_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/Continuous_Kshap.csv')
samcontrib_continuous = pd.read_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/Continuous_Sshap.csv')
trecontrib_continuous = pd.read_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/Continuous_Tshap.csv')
limecontrib_continuous = pd.read_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/Continuous_lime.csv')
ticontrib_continuous = pd.read_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/Continuous_ti.csv')
dicecontrib_continuous = pd.read_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/Continuous_dice.csv')
all_fi_continuous = pd.read_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/Continuous_localExplainMethods.csv')
```

### ▼ Binary Contributions

```
#VAR binary
gscontrib_binary = pd.read_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/Binary_glosur.csv')
kercontrib_binary = pd.read_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/Binary_Kshap.csv')
samcontrib_binary = pd.read_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/Binary_Sshap.csv')
trecontrib_binary = pd.read_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/Binary_Tshap.csv')
limecontrib_binary = pd.read_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/Binary_lime.csv')
ticontrib_binary = pd.read_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/Binary_ti.csv')
dicecontrib_binary = pd.read_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/Binary_dice.csv')
all_fi_binary = pd.read_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/Binary_localExplainMethods.csv')
```

## ✓ Checkpoint: explain

```
#TOOLS
all_fi.fillna(0, inplace=True)
all_fi.iloc[:, :-1] = np.abs(all_fi.iloc[:, :-1])
all_fi.reset_index(drop=True, inplace=True)
label="Dx:Cancer"
methods=all_fi['Method'].to_list()
weights=[gscontrib, kercontrib, trecontrib, samcontrib, limecontrib, ticontrib, dicecontrib]
```

```
#Normalize
gscontrib_norm=gscontrib.div(gscontrib.sum(axis=1), axis=0)
kercontrib_norm=kercontrib.div(kercontrib.sum(axis=1), axis=0)
samcontrib_norm=samcontrib.div(samcontrib.sum(axis=1), axis=0)
trecontrib_norm=trecontrib.div(trecontrib.sum(axis=1), axis=0)
limecontrib_norm=limecontrib.div(limecontrib.sum(axis=1), axis=0)
ticontrib_norm=ticontrib.div(ticontrib.sum(axis=1), axis=0)
dicecontrib_norm=dicecontrib.div(dicecontrib.sum(axis=1), axis=0)
```

```
#One Instance
risk_factor_df.describe().iloc[1]
```

Age	29.375075
Number of sexual partners	2.555158
First sexual intercourse	17.480024
Num of pregnancies	2.267740
Smokes	0.077519
Smokes (years)	1.362854
Smokes (packs/year)	0.796284
Hormonal Contraceptives	0.586166
Hormonal Contraceptives (years)	2.368868
IUD	0.129398
IUD (years)	1.147927
STDs	0.047108
STDs (number)	0.079308
STDs:condylomatosis	0.026237
STDs:cervical condylomatosis	0.000000
STDs:vaginal condylomatosis	0.002385
STDs:vulvo-perineal condylomatosis	0.025641
STDs:syphilis	0.010733
STDs:pelvic inflammatory disease	0.000596
STDs:genital herpes	0.000596
STDs:molluscum contagiosum	0.000596
STDs:AIDS	0.000000
STDs:HIV	0.010733
STDs:Hepatitis B	0.000596
STDs:HPV	0.001193
STDs: Number of diagnosis	0.044723
STDs: Time since first diagnosis	4.245497
STDs: Time since last diagnosis	3.287024
Dx:CIN	0.005367
Dx:HPV	0.412045
Dx	0.388790
Hinselmann	0.030411
Schiller	0.115683
Citology	0.067382
Biopsy	0.085868
total_std	0.079308
total_tests	0.536076
Dx:Cancer	0.499106
Name: mean, dtype: float64	

```
xx=risk_factor_df.describe().iloc[1]
```

```
instance=3
```

```

xx=X_test.iloc[instance]
idx=list(xx.to_numpy().nonzero()[0])
xx=xx.to_frame()
xxx=xx.T.columns
new=pd.DataFrame()
for i in range(len(xxx)):
    if i in idx:
        new[xxx[i]]=xx.T[xxx[i]]

new.T.round(2)

```

	3
<b>Age</b>	27.0
<b>Number of sexual partners</b>	2.0
<b>First sexual intercourse</b>	19.0
<b>Num of pregnancies</b>	2.0
<b>Hormonal Contraceptives</b>	1.0
<b>Hormonal Contraceptives (years)</b>	7.0
<b>STDs: Time since first diagnosis</b>	4.0
<b>STDs: Time since last diagnosis</b>	3.0

```

with open('instance.tex','w') as tf:
    tf.write(new.T.round(2).to_latex())

```

```

#Instance dataframe
one_instance=[]

for i in range(len(methods)):
    one_instance.append(weights[i].iloc[instance])

one_instance=pd.DataFrame(one_instance, columns=X_test.columns)
one_instance['methods']=methods
one_instance.set_index('methods', inplace=True)

# one_instance.to_csv('/content/drive/My Drive/DL4H_Sp24_Final_Project/one_instance.csv')

```

```
one_instance
```

	Age	Number of sexual partners	First sexual intercourse	Num of pregnancies	Smokes	Smokes (years)	Smokes (packs/year)	Hormonal Contraceptives	Hormonal Contraceptives (years)	IUD	...	STI Number diagnos:
	<b>methods</b>											
<b>Surrogates</b>	-0.553312	0.014681	-0.073233	0.225368	0.097137	-0.729476	0.036396	-0.038294	0.381243	0.000000	...	0.000
<b>KSHAP</b>	-0.006393	-0.001116	0.011805	0.001627	0.003127	-0.034773	-0.050208	-0.018699	-0.001624	0.000000	...	0.000
<b>TSHAP</b>	-0.009806	-0.005322	0.002830	-0.000960	0.004535	-0.010121	-0.013297	-0.025939	0.006601	0.001960	...	0.000
<b>SSHAP</b>	-0.006688	-0.014051	0.003915	-0.000870	0.004158	-0.002152	-0.002466	-0.029883	0.000344	0.007551	...	0.000
<b>LIME</b>	-0.002613	0.002087	0.029688	0.000697	0.091447	-0.030916	-0.016843	-0.091805	0.017501	0.036938	...	0.030
<b>TI</b>	0.016134	-0.007890	0.058177	0.008559	0.007480	-0.018715	-0.016275	-0.025908	0.027821	-0.006048	...	0.002
<b>DICE</b>	0.200000	0.000000	0.000000	0.000000	0.000000	0.000000	0.100000	0.100000	0.000000	0.000000	...	0.000

```

instance=291
var='W'
maxx=10
f=''
vale=0

```

```

# Initialize a LIME Explainer for tabular data, specifying the training dataset, the problem type, and the feature names
explainer = lime.lime_tabular.LimeTabularExplainer(X_train.values, mode='classification', feature_names=X_test.columns)

# Explain the prediction of a specific instance from the test dataset using the trained model
exp = explainer.explain_instance(X_test.iloc[instance], model.predict_proba, num_features=X_test.shape[1])

```

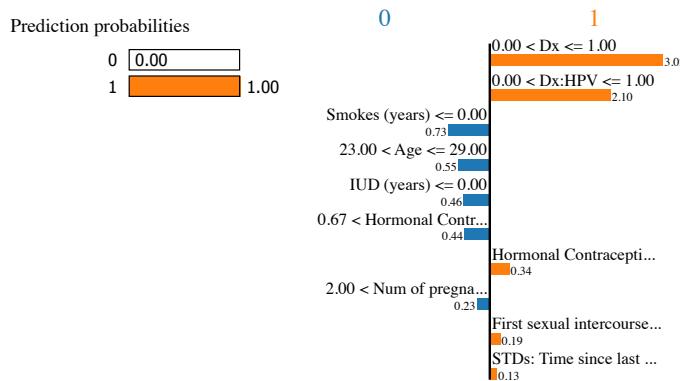
The model is confident this instance is of class 1.

```
# glosar contribution
items = gscontrib.iloc[instance].to_dict()
t = []
count=0
for i, item in enumerate(items):
    if abs(items[item]) > 0.0 :
        t.append((i, items[item]))

t = sorted(t, key=lambda tup: abs(tup[1]), reverse=True)

exp_test = {1: t[0:maxx]}

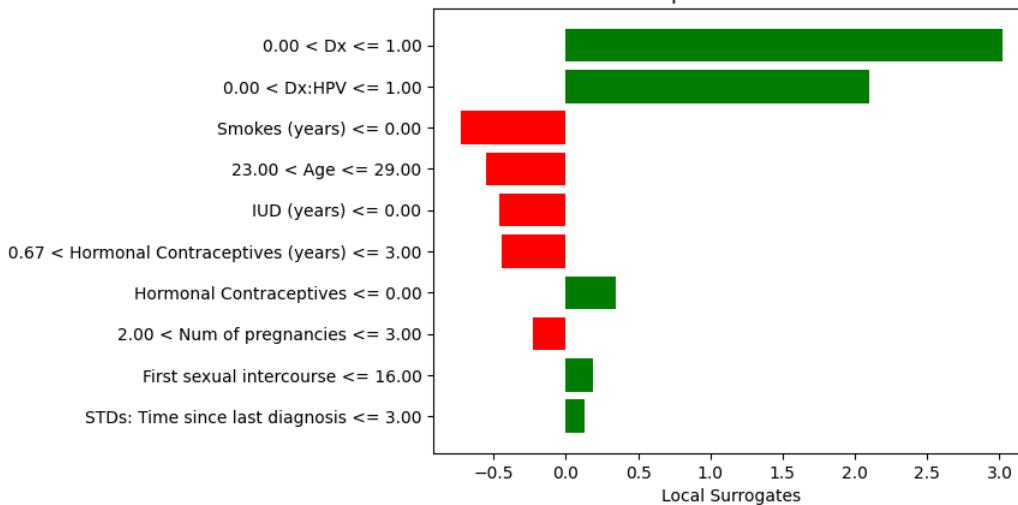
exp.local_exp = exp_test
exp.show_in_notebook(show_table=False, show_predicted_value=False)
```



```
%matplotlib inline
fig = exp.as_pyplot_figure()
plt.xlabel("Local Surrogates")
```

Text(0.5, 0, 'Local Surrogates')

Local explanation for class 1



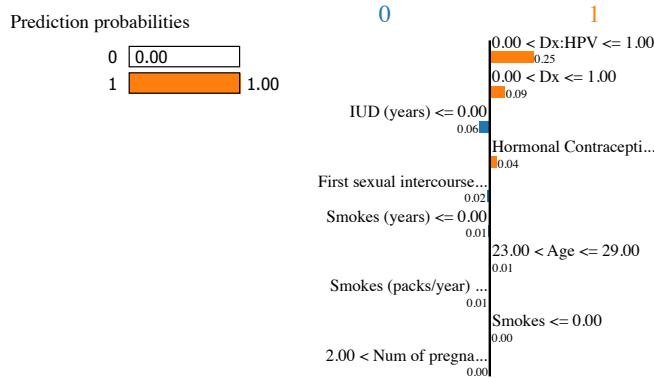
```
# fig.savefig('/content/drive/My Drive/DL4H_Sp24_Final_Project/'+str(var)+'surrogate'+str(instance)+str(f)+'.png', bbox_inches='tight')
```

```
items = kercontrib.iloc[instance].to_dict()
t = []
count=0
for i, item in enumerate(items):
    if abs(items[item]) > 0.0 :
        t.append((i, items[item]))

t = sorted(t, key=lambda tup: abs(tup[1]), reverse=True)

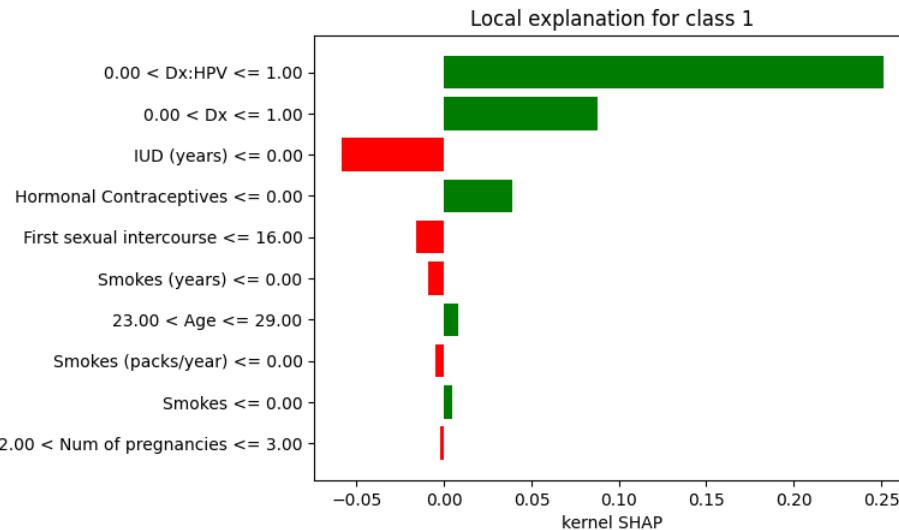
exp_test = {1: t[0:maxx]}

exp.local_exp = exp_test
exp.show_in_notebook(show_table=False, show_predicted_value=False)
```



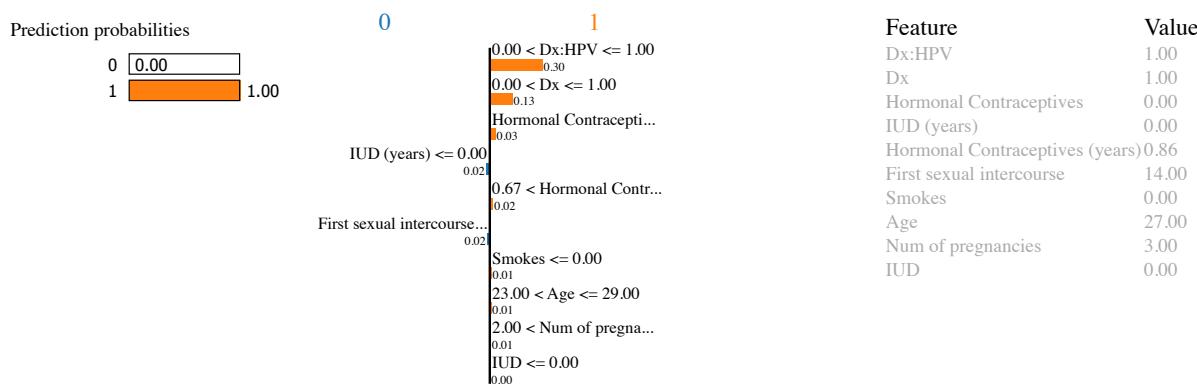
```
%matplotlib inline
fig = exp.as_pyplot_figure()
plt.xlabel("kernel SHAP")
# fig.savefig('/content/drive/My Drive/DL4H_Sp24_Final_Project/'+str(var)+'kernelSHAP'+str(instance)+str(f)+'.png', bbox_inches='tight')
```

Text(0.5, 0, 'kernel SHAP')



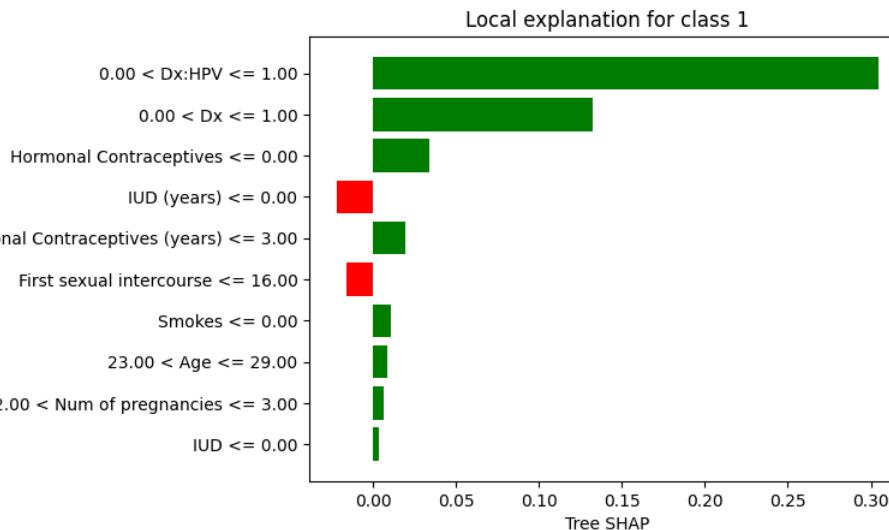
```
items = trecontrib.iloc[instance].to_dict()
t = []
count=0
for i, item in enumerate(items):
    if abs(items[item]) > 0.0 :
        t.append((i, items[item]))
t = sorted(t, key=lambda tup: abs(tup[1]), reverse=True)
exp_test = {1: t[0:maxx]}

exp.local_exp = exp_test
exp.show_in_notebook(show_table=True, show_predicted_value=False)
```



```
%matplotlib inline
fig = exp.as_pyplot_figure()
plt.xlabel("Tree SHAP")
# fig.savefig('/content/drive/My Drive/DL4H_Sp24_Final_Project/'+str(var)+'treeSHAP'+str(instance)+str(f)+'.png', bbox_inches='tight')
```

```
Text(0.5, 0, 'Tree SHAP')
```



```
items = samcontrib.iloc[instance].to_dict()
```

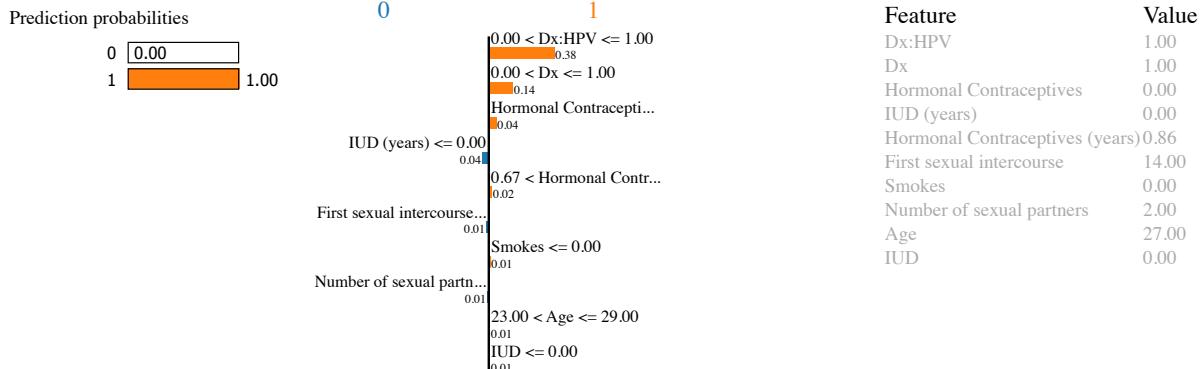
```
t = []
count=0
for i, item in enumerate(items):
    if abs(items[item]) > 0.0 :
        t.append((i, items[item]))
        count+=1
```

```
t = sorted(t, key=lambda tup: abs(tup[1]), reverse=True)
```

```
exp_test = {1: t[0:maxx]}
```

```
exp.local_exp = exp_test
```

```
exp.show_in_notebook(show_table=True, show_predicted_value=False)
```



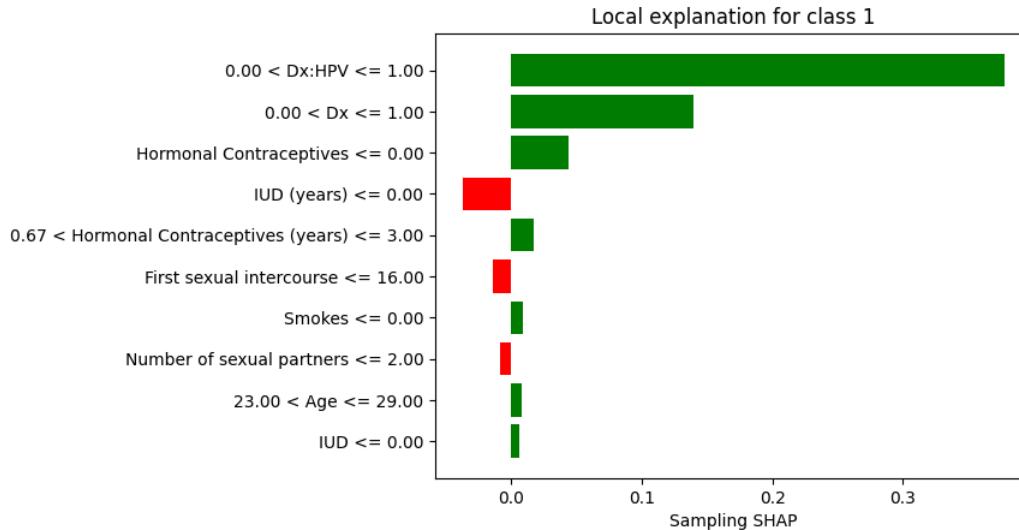
```
%matplotlib inline
```

```
fig = exp.as_pyplot_figure()
```

```
plt.xlabel("Sampling SHAP")
```

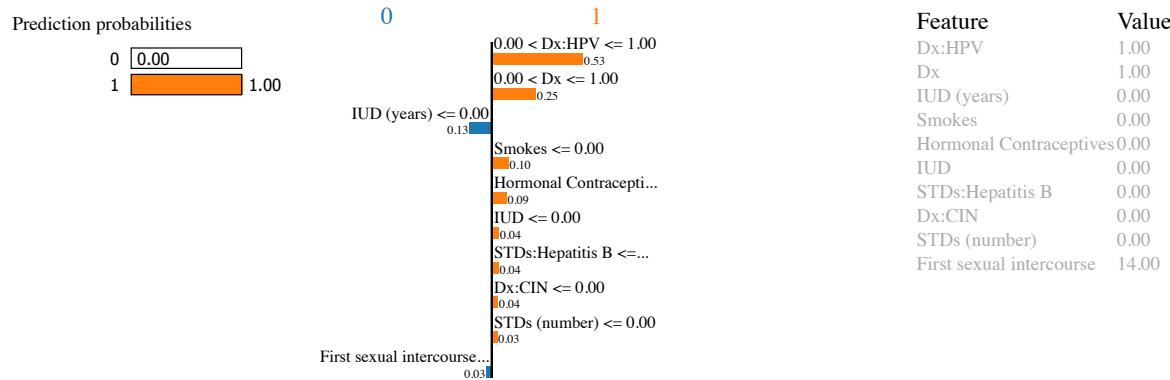
```
# fig.savefig('/content/drive/My Drive/DL4H_Sp24_Final_Project/'+str(var)+'samplingSHAP'+str(instance)+str(f)+'.png', bbox_inches='tight')
```

```
Text(0.5, 0, 'Sampling SHAP')
```



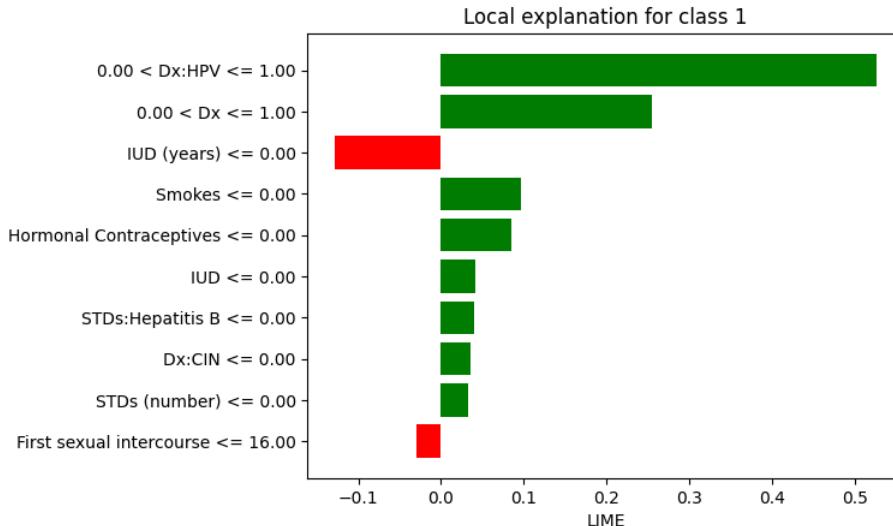
```
items = limecontrib.iloc[instance].to_dict()
t = []
count=0
for i, item in enumerate(items):
    if abs(items[item]) > 0.0 :
        t.append((i, items[item]))
t = sorted(t, key=lambda tup: abs(tup[1]), reverse=True)
exp_test = {1: t[0:maxx]}

exp.local_exp = exp_test
exp.show_in_notebook(show_table=True, show_predicted_value=False)
```



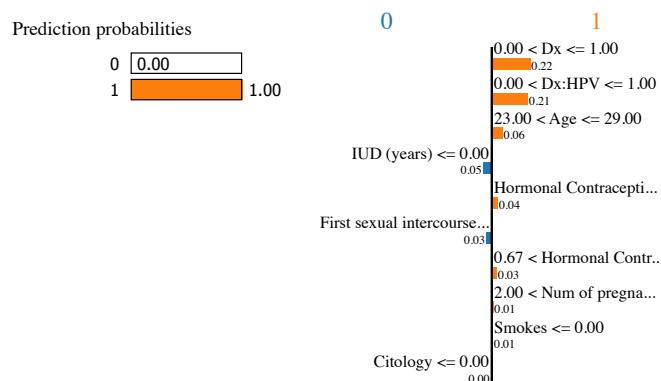
```
%matplotlib inline
fig = exp.as_pyplot_figure()
plt.xlabel("LIME")
# fig.savefig('/content/drive/My Drive/DL4H_Sp24_Final_Project/' + str(var) + 'lime' + str(instance) + str(f) + '.png', bbox_inches='tight')
```

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



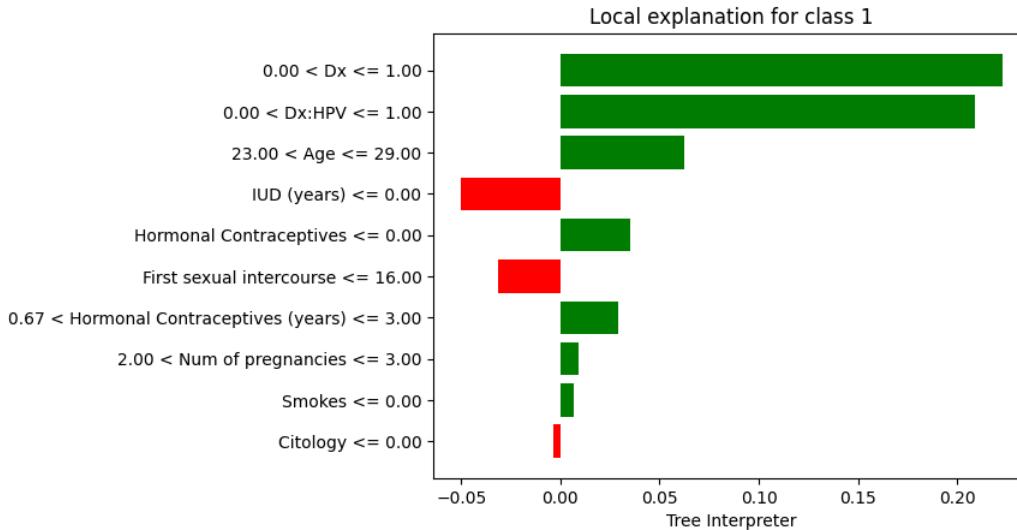
```
items = ticontrib.iloc[instance].to_dict()
t = []
count=0
for i, item in enumerate(items):
    if abs(items[item]) > 0.0 :
        t.append((i, items[item]))
t = sorted(t, key=lambda tup: abs(tup[1]), reverse=True)
exp_test = {1: t[0:maxx]}

exp.local_exp = exp_test
exp.show_in_notebook(show_table=False, show_predicted_value=False)
```



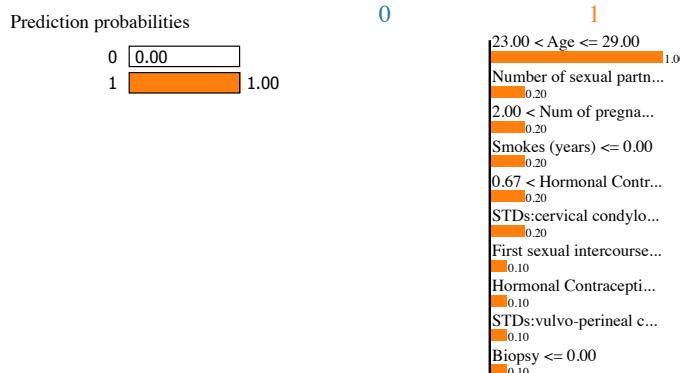
```
%matplotlib inline
fig = exp.as_pyplot_figure()
plt.xlabel("Tree Interpreter")
# fig.savefig('/content/drive/My Drive/DL4H_Sp24_Final_Project/' + str(var) + 'ti' + str(instance) + str(f) + '.png', bbox_inches='tight')
```

```
Text(0.5, 0, 'Tree Interpreter')
```



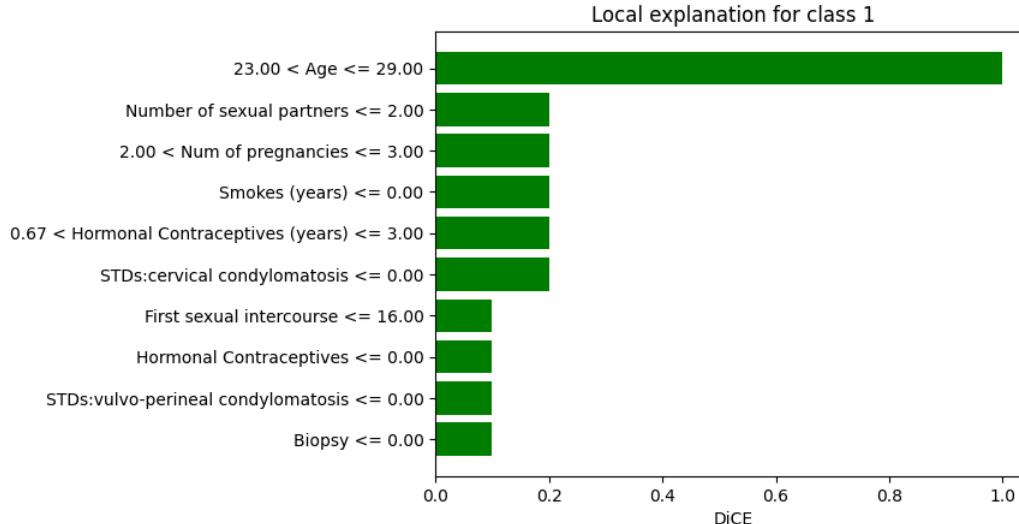
```
items = dicecontrib.iloc[instance].to_dict()
t = []
count=0
for i, item in enumerate(items):
    if abs(items[item]) > 0.0 :
        t.append((i, items[item]))
t = sorted(t, key=lambda tup: abs(tup[1]), reverse=True)
exp_test = {1: t[0:maxx]}

exp.local_exp = exp_test
exp.show_in_notebook(show_table=False,show_predicted_value=False)
```



```
%matplotlib inline
fig = exp.as_pyplot_figure()
plt.xlabel("Dice")
# fig.savefig('/content/drive/My Drive/DL4H Sp24 Final Project/' + str(var) + 'dice' + str(instance) + str(f) + '.png', bbox_inches='tight')
```

Text(0.5, 0, 'DiCE')



## ✓ Checkpoint ROAR

The Faithfulness Metric: RemOve And Retrain (ROAR) (Hooker et al., 2018) is a machine learning interpretability metric that involves iteratively removing a subset of features from a dataset, retraining the model on the reduced dataset, and then evaluating the changes in model accuracy or feature importance.

```

from sklearn.model_selection import cross_val_score

def roar(featImp, feature_to_predict, datapath, savepath, dataname):
    # Define line styles for plotting
    a = ['ro--', 'go--', 'mo--', 'yo--', 'ko--', 'bo--']
    # Define percentages of features to remove in each iteration
    pourc = [0, 10, 20, 30, 40, 60, 70, 90]
    # Set font size for plots
    font = {'size': 14}
    plt.rc('font', **font)

    # Iterate over each row of feature importances (each method's importance)
    for k in range(featImp.shape[0]):
        accuracies = []
        # Iterate over defined percentages to remove features incrementally
        for i in pourc:
            # Extract feature importances, assuming 'Method' column exists and needs to be excluded
            fi = featImp.iloc[k, :].drop('Method')
            # Sort features by importance
            fi = fi.to_dict()
            fi = dict(sorted(fi.items(), key=lambda x: x[1], reverse=True))
            fii = list(fi.keys())

            # Load the dataset
            df = pd.read_csv(datapath)
            # Calculate the number of top features to remove based on percentage
            top = int(len(fii) * i) / 100
            if top >= len(fii):
                print(f"Skipping removal of top {top} features as it exceeds available features.")
                accuracies.append(None)
                continue
            remaining_features = fii[top:] + [feature_to_predict]

            print(f"Removing top {top} features, which are: {fii[:top]}")

            # Select the remaining features in the dataset
            df = df[remaining_features]
            X = df.drop(feature_to_predict, axis=1).values
            y = df[feature_to_predict].values

            # Check if there are any features left to train the model
            if X.shape[1] == 0:
                print("No features left to train the model.")
                accuracies.append(None)
                continue

            # Initialize the classifier and perform cross-validation
            model = RandomForestClassifier(random_state=42)
            try:
                scores = cross_val_score(model, X, y, cv=10)
                accuracies.append(np.mean(scores))
            except Exception as e:
                print(f"Error while fitting the model: {e}")
                accuracies.append(None)

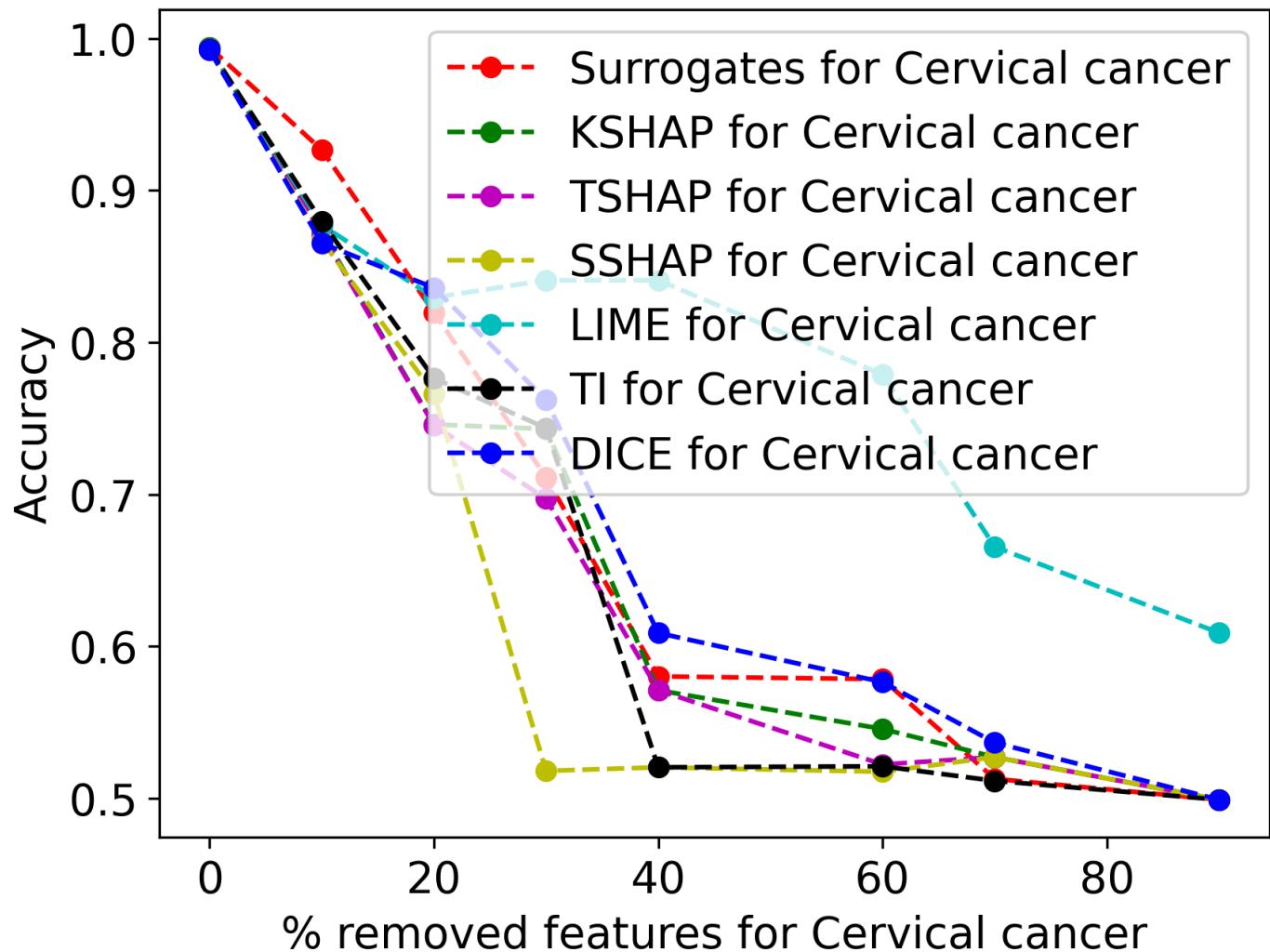
        # Plot the results for the current feature importance row
        plt.plot(pourc, accuracies, a[k], label=f"{featImp.iloc[k, :]['Method']} for {dataname}")

    # Configure and display the plot
    plt.xlabel('% removed features for ' + dataname)
    plt.ylabel('Accuracy')
    plt.legend(loc='upper right')
    # plt.savefig(savepath + 'roar.png', bbox_inches='tight', dpi=300)
    plt.show()

datapath=root + '/Rcancer2.csv'
savepath= '/content/drive/My Drive/DL4H_Sp24_Final_Project/'
dataname='Cervical cancer'
# print(all_fi.columns)
# roar(all_fi, label, datapath, savepath, dataname)

from PIL import Image
im = Image.open(root+/"roar.png")
im

```



✗ SHAPASH Contribution Plots (Age)

```

from shapash.explainer.consistency import Consistency
from shapash import SmartExplainer

print("Training Data Shape:", X_train.shape)
print("Testing Data Shape:", X_test.shape)
print("Training Features:", X_train.columns.tolist())
print("Testing Features:", X_test.columns.tolist())

cns=Consistency()
xpl = SmartExplainer(model=model)
xpl.compile(x=X_test)

from sklearn.ensemble import RandomForestClassifier
xpl = SmartExplainer(model=model)
xpl.compile(
    x=X_test,
)

```

```

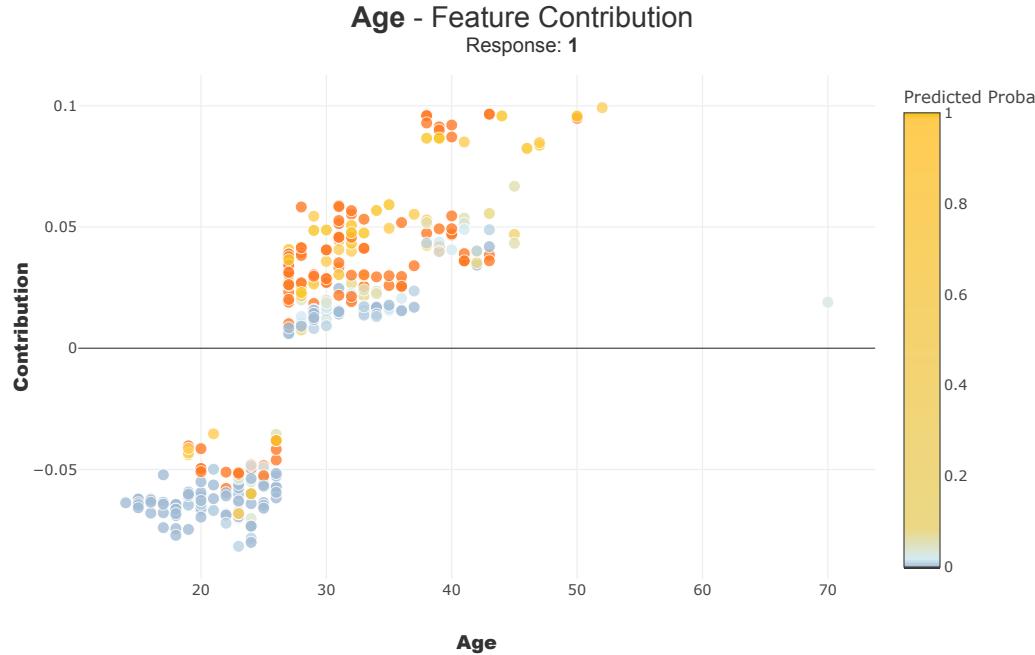
Training Data Shape: (1341, 35)
Testing Data Shape: (336, 35)
Training Features: ['Age', 'Number of sexual partners', 'First sexual intercourse', 'Num of pregnancies', 'Smokes', 'Smokes (years)', 'Smo
Testing Features: ['Age', 'Number of sexual partners', 'First sexual intercourse', 'Num of pregnancies', 'Smokes', 'Smokes (years)', 'Smok
INFO: Shap explainer type - <shap.explainers._tree.TreeExplainer object at 0x7f6850f84310>
INFO: Shap explainer type - <shap.explainers._tree.TreeExplainer object at 0x7f684a507970>

```

```

img=xpl.plot.contribution_plot(0)
img.show()

```



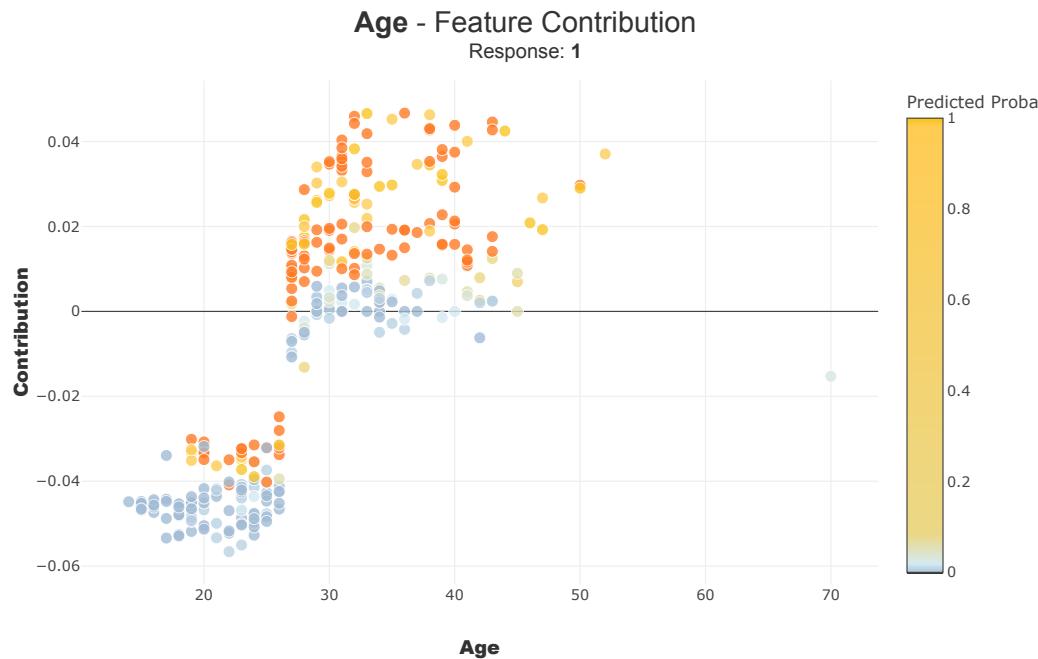
```
# img.write_image('/content/drive/My Drive/DL4H_Sp24_Final_Project/contribage.png')
```

```

xpl = SmartExplainer(model=model)
xpl.compile(x=X_test, contributions=kercontribution)

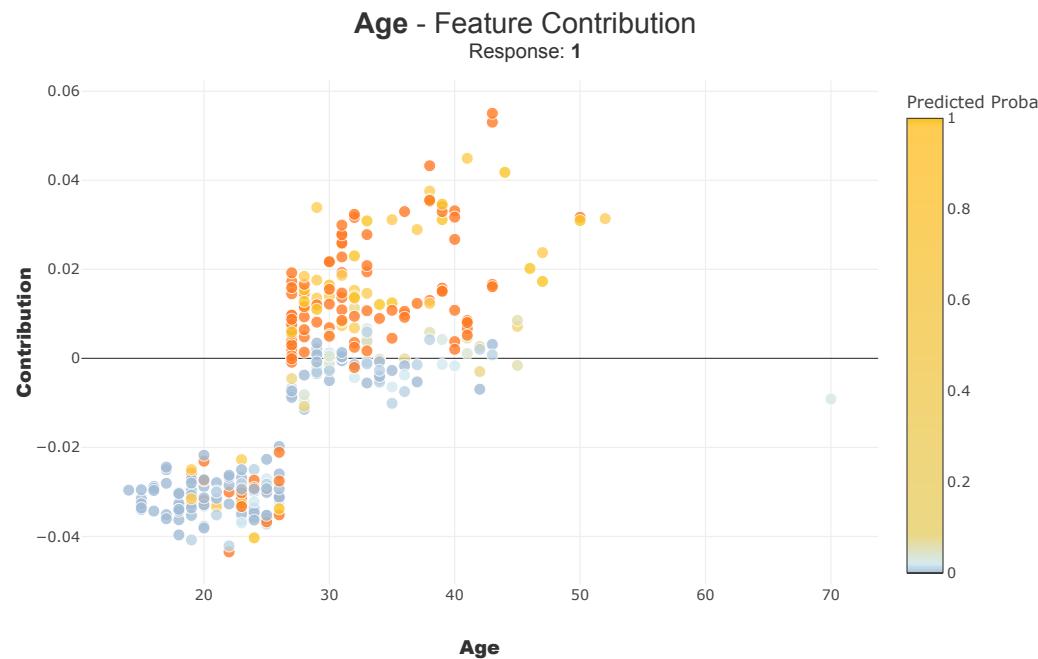
img=xpl.plot.contribution_plot(0)
img.show()

```



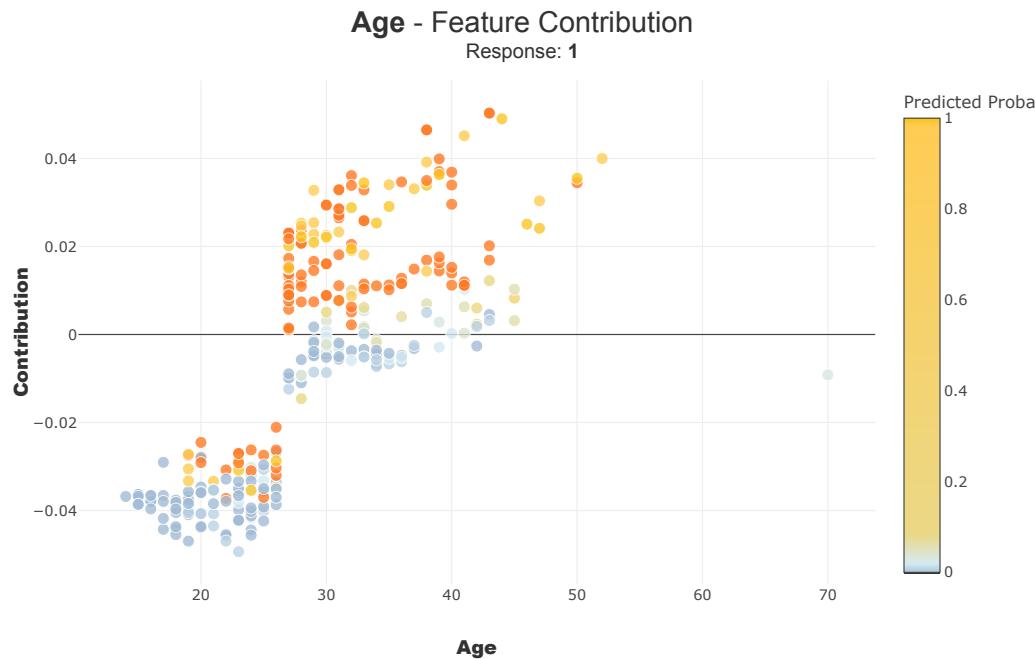
```
# img.write_image('/content/drive/My Drive/DL4H_Sp24_Final_Project/contribagekernel.png')
```

```
xpl = SmartExplainer(model=model)
xpl.compile(x=X_test, contributions=samcontrib)
img=xpl.plot.contribution_plot(0)
img.show()
```



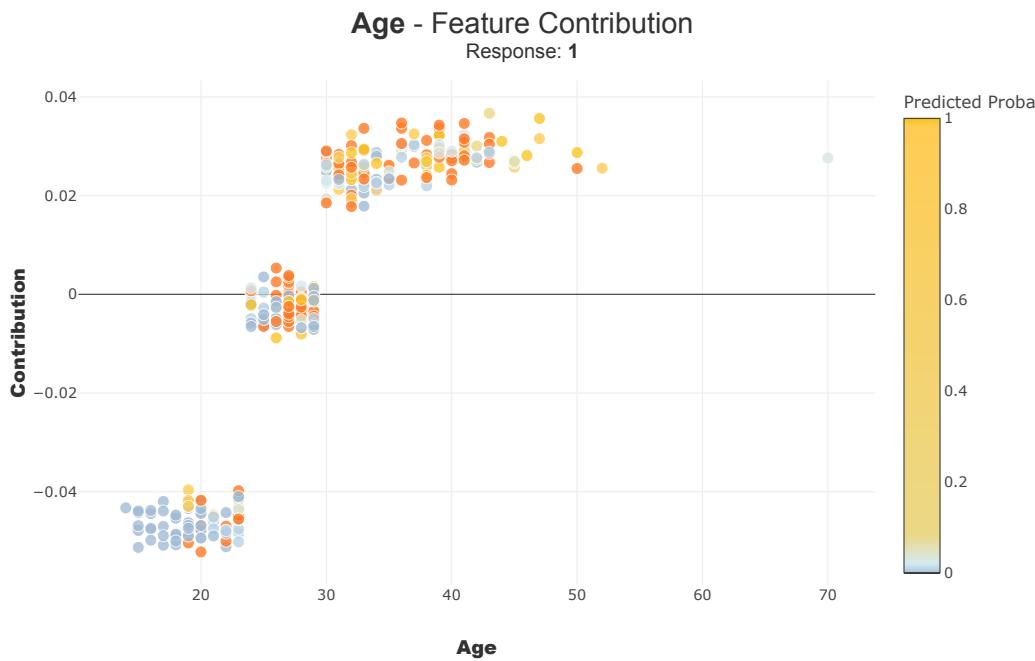
```
# img.write_image('/content/drive/My Drive/DL4H_Sp24_Final_Project/contribagesampling.png')
```

```
xpl = SmartExplainer(model=model)
xpl.compile(x=X_test, contributions=trecontrib)
img=xpl.plot.contribution_plot(0)
img.show()
```



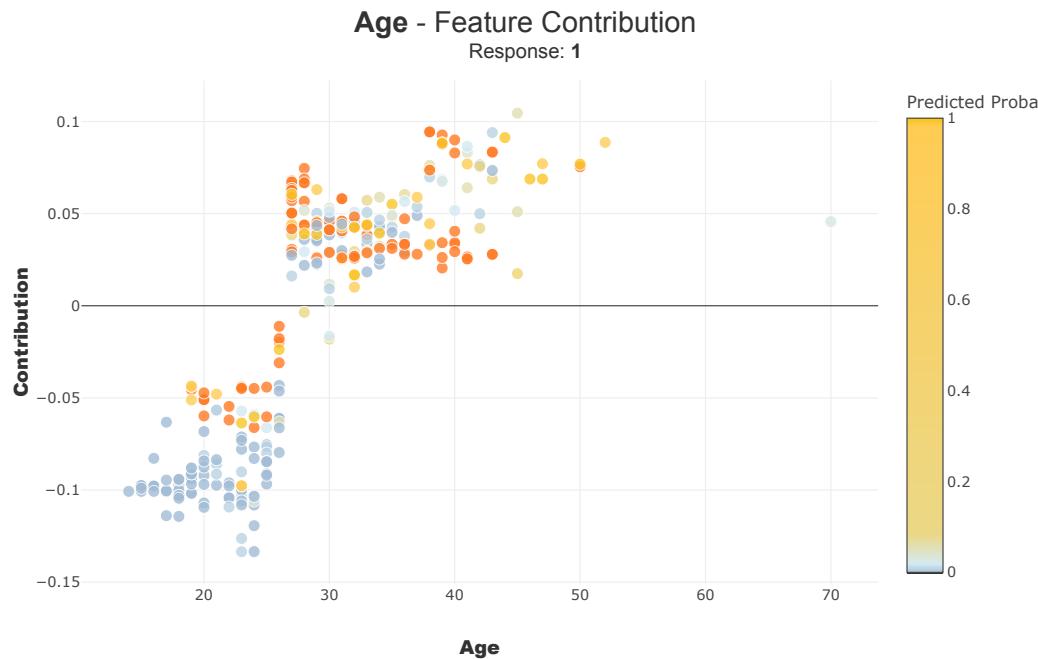
```
# img.write_image('/content/drive/My Drive/DL4H_Sp24_Final_Project/contribagetree.png')
```

```
xpl = SmartExplainer(model=model)
xpl.compile(x=X_test, contributions=limecontrib)
img=xpl.plot.contribution_plot(0)
img.show()
```



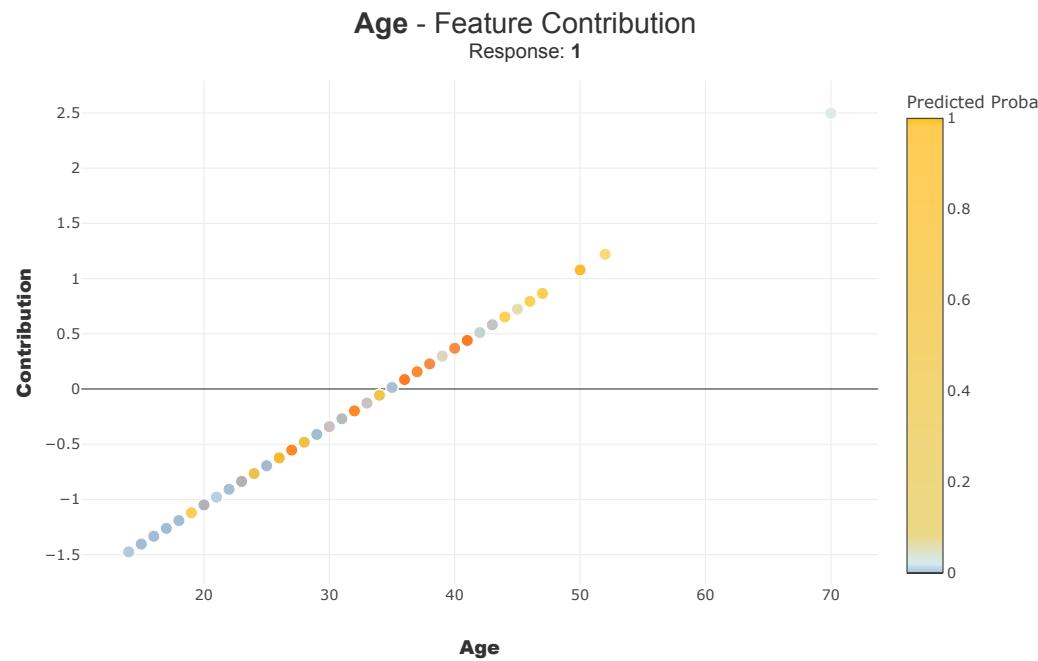
```
# img.write_image('/content/drive/My Drive/DL4H_Sp24_Final_Project/contribaglime.png')
```

```
xpl = SmartExplainer(model=model)
xpl.compile(x=X_test, contributions=ticontrib)
img=xpl.plot.contribution_plot(0)
img.show()
```



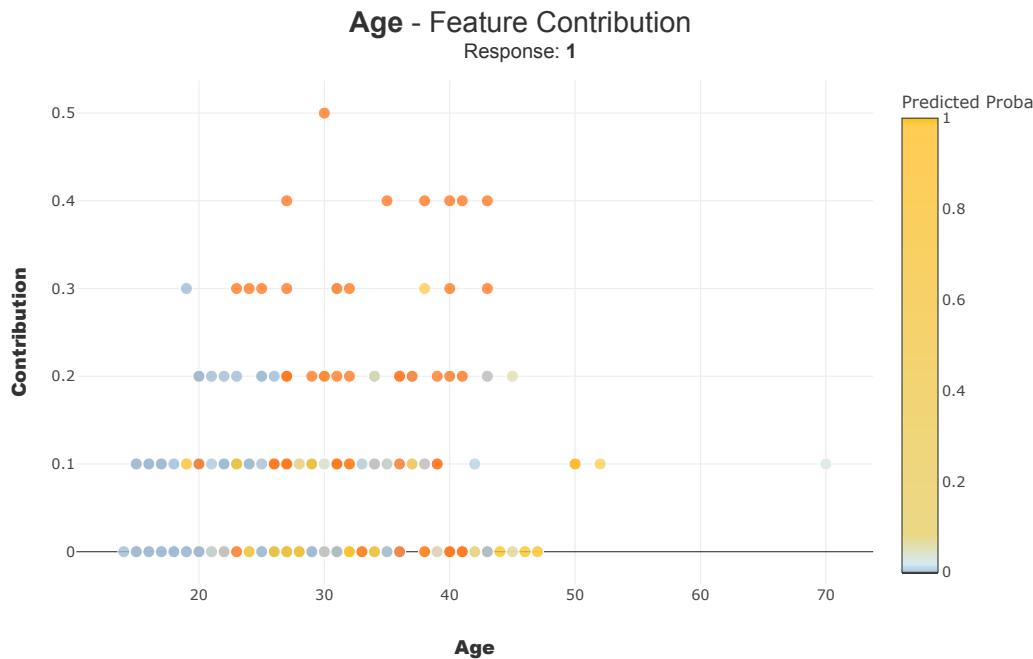
```
# img.write_image('/content/drive/My Drive/DL4H_Sp24_Final_Project/contribageti.png')
```

```
xpl = SmartExplainer(model=model)
xpl.compile(x=X_test, contributions=gscontrib)
img=xpl.plot.contribution_plot(0)
img.show()
```



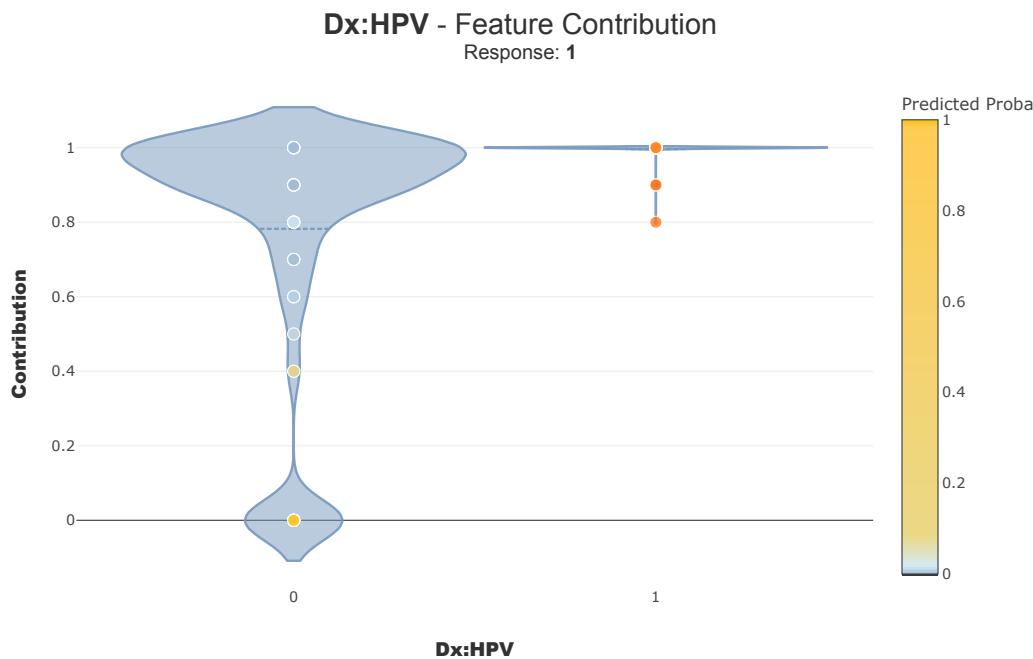
```
# img.write_image('/content/drive/My Drive/DL4H_Sp24_Final_Project/contribageGlosur.png')
```

```
xpl = SmartExplainer(model=model)
dicecontrib = dicecontrib[X_test.columns]
xpl.compile(x=X_test, contributions=dicecontrib)
img=xpl.plot.contribution_plot(0)
img.show()
```



```
# img.write_image('/content/drive/My Drive/DL4H_Sp24_Final_Project/contribageDice.png')

fig_image=xpl.plot.contribution_plot(29)
fig_image.show()
# plt.savefig('/content/drive/My Drive/DL4H_Sp24_Final_Project/contdxhpv.png')
```



## ▼ Consistency Plots

```
pairwise_consistency=cns.calculate_all_distances(methods, weights)

test=pairwise_consistency[1].round(2)

test.style.background_gradient(cmap='Paired_r')
```

	<b>Surrogates</b>	<b>KSHAP</b>	<b>TSHAP</b>	<b>SSHAP</b>	<b>LIME</b>	<b>TI</b>	<b>DICE</b>
<b>Surrogates</b>	0.000000	0.510000	0.450000	<b>0.590000</b>	0.500000	0.500000	<b>1.390000</b>
<b>KSHAP</b>	0.510000	0.000000	0.240000	<b>0.320000</b>	<b>0.390000</b>	0.430000	1.260000
<b>TSHAP</b>	<b>0.450000</b>	0.240000	0.000000	0.250000	<b>0.350000</b>	<b>0.360000</b>	1.260000
<b>SSHAP</b>	<b>0.590000</b>	<b>0.320000</b>	0.250000	0.000000	0.450000	<b>0.350000</b>	1.200000
<b>LIME</b>	0.500000	<b>0.390000</b>	<b>0.350000</b>	0.450000	0.000000	0.510000	<b>1.320000</b>
<b>TI</b>	0.500000	0.430000	<b>0.360000</b>	<b>0.350000</b>	0.510000	0.000000	1.280000
<b>DICE</b>	<b>1.390000</b>	1.260000	1.260000	1.200000	1.320000	1.280000	0.000000

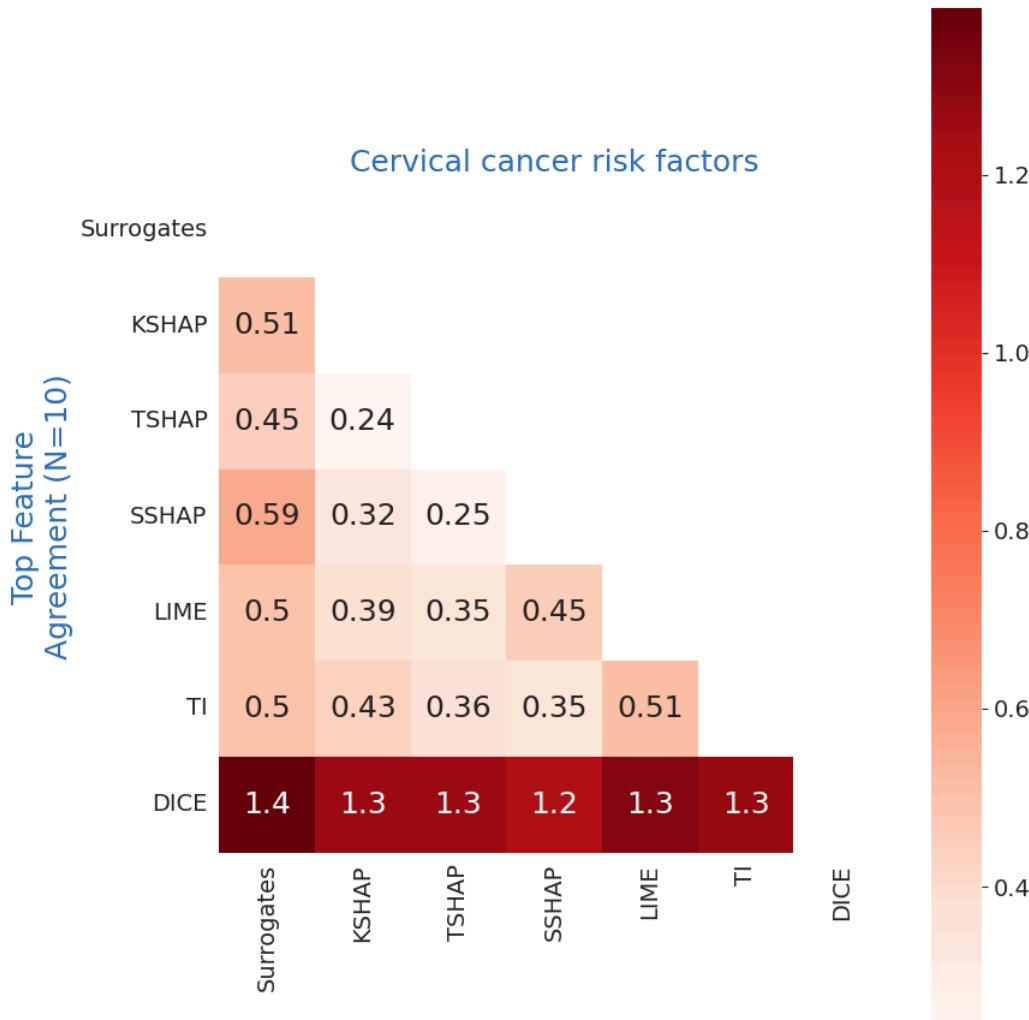
```
root = 'DL4H_Sp24_Final_Project'
```

```
with open(root + '/consistency.tex','w') as tf:
    tf.write(test.to_latex())
```

```
corr = pairwise_consistency[1]
mask = np.zeros_like(corr)
mask[np.triu_indices_from(mask)] = True
fig = plt.figure(figsize=(9, 11))
with sns.axes_style("white"):

    ax = sns.heatmap(corr, mask=mask, square=True, annot=True, annot_kws={'fontsize': 18},
                      xticklabels=methods, yticklabels=methods, cmap="Reds", cbar=True)
    ax.set_title("Cervical cancer risk factors", color='xkcd:medium blue', fontsize=18)
    ax.set_ylabel('Top Feature\nAgreement (N=10)', color='xkcd:medium blue', fontsize=18)
```

```
plt.show()
```



```
# fig.savefig(root+'/consistency_png', bbox_inches='tight', dpi=300)
```

```
for i in pairwise_consistency[1].columns:
    print(i, round(np.mean(pairwise_consistency[1][i]),2))

Surrogates 0.56
KSHAP 0.45
TSHAP 0.42
SSHAP 0.45
LIME 0.5
TI 0.49
DICE 1.1
```

## ▼ Compactness

```
def get_distance(selection, contributions, mode, nb_features):

    if mode == "classification" and len(contributions) == 2:
        contributions = contributions[1]
    assert nb_features <= contributions.shape[1]

    contributions = contributions.loc[selection].values
    top_features = np.array([sorted(row, key=abs, reverse=True) for row in contributions])[:, :nb_features]
    output_top_features = np.sum(top_features[:, :], axis=1)
    output_all_features = np.sum(contributions[:, :], axis=1)

    if mode == "regression":
        distance = abs(output_top_features - output_all_features) / abs(output_all_features)
    elif mode == "classification":
        distance = abs(output_top_features - output_all_features)
    return distance

def get_min_nb_features(selection, contributions, mode, distance):

    assert 0 <= distance <= 1

    if mode == "classification" and len(contributions) == 2:
        contributions = contributions[1]
    contributions = contributions.loc[selection].values
    features_needed = []
    # For each instance, add features one by one (ordered by SHAP) until we get close enough
    for i in range(contributions.shape[0]):
        ids = np.flip(np.argsort(np.abs(contributions[i, :])))
        output_value = np.sum(contributions[i, :])

        score = 0
        for j, idx in enumerate(ids):
            # j : number of features needed
            # idx : positions of the j top shap values
            score += contributions[i, idx]
            # CLOSE_ENOUGH
            if mode == "regression":
                if abs(score - output_value) < distance * abs(output_value):
                    break
            elif mode == "classification":
                if abs(score - output_value) < distance:
                    break
            features_needed.append(j + 1)
    return features_needed

def compute_features_compacity(case, contributions, selection, distance, nb_features):
    #if (case == "classification") and (len(classes) > 2):
    #    raise AssertionError("Multi-class classification is not supported")

    features_needed = get_min_nb_features(selection, contributions, case, distance)
    distance_reached = get_distance(selection, contributions, case, nb_features)
    # We clip large approximations to 100%
    distance_reached = np.clip(distance_reached, 0, 1)

    return {"features_needed": features_needed, "distance_reached": distance_reached}

compacities=[]

for weight in weights:
    rr=compute_features_compacity(case="classification", contributions=weight, selection=list(range(0, len(X_test))), distance=.9, nb_features=5)
    #rr=compute_features_compacity(case="classification", contributions=weight, selection=[instance], distance=0.9, nb_features=5)
    compacities.append(pd.DataFrame.from_dict(rr))
```

```

maxx=[]
for c in compacities:
    maxx.append(c.iloc[c.distance_reached.idxmax()].tolist())
compacity=pd.DataFrame(data=maxx, columns=['features_needed', 'distance_reached'])
compacity['Method']=methods
compacity.set_index('Method', drop=True).round(2)

```

#### features\_needed distance\_reached

	Method	
<b>Surrogates</b>	2.0	1.00
<b>KSHAP</b>	1.0	0.22
<b>TSHAP</b>	1.0	0.16
<b>SSHAP</b>	1.0	0.14
<b>LIME</b>	1.0	0.48
<b>TI</b>	1.0	0.20
<b>DICE</b>	9.0	1.00

```

with open(root+'/compactness'+str(instance)+'.tex','w') as tf:
    tf.write(compacity.to_latex())

```

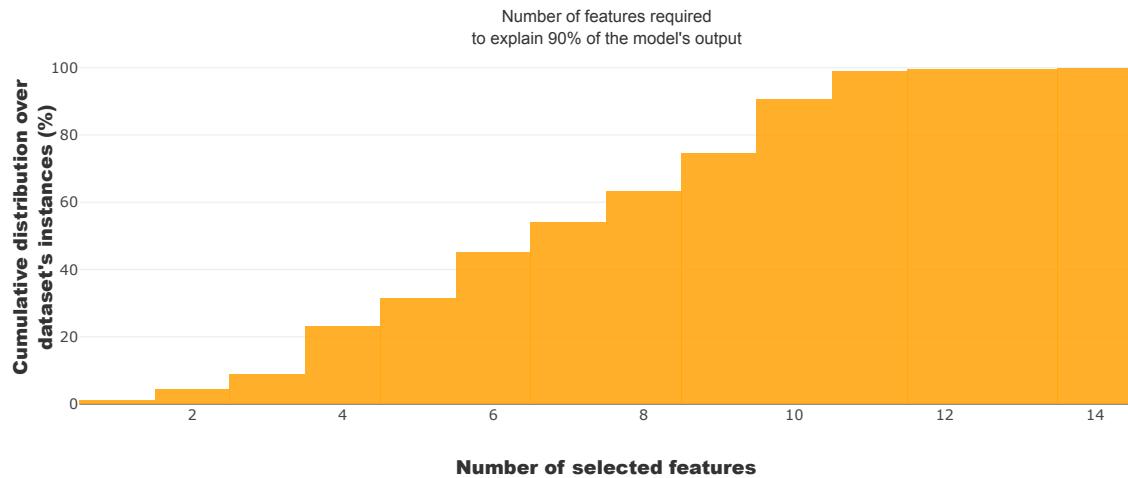
```

xpl = SmartExplainer(model=model)
xpl.compile(x=X_test, contributions=gscontrib)
img=xpl.plot.compacity_plot()
img.show()

```

## Compacity o

How many variables are enough



```
# img.write_image('/content/drive/My Drive/DL4H_Sp24_Final_Project/compactGlosur.png')
```

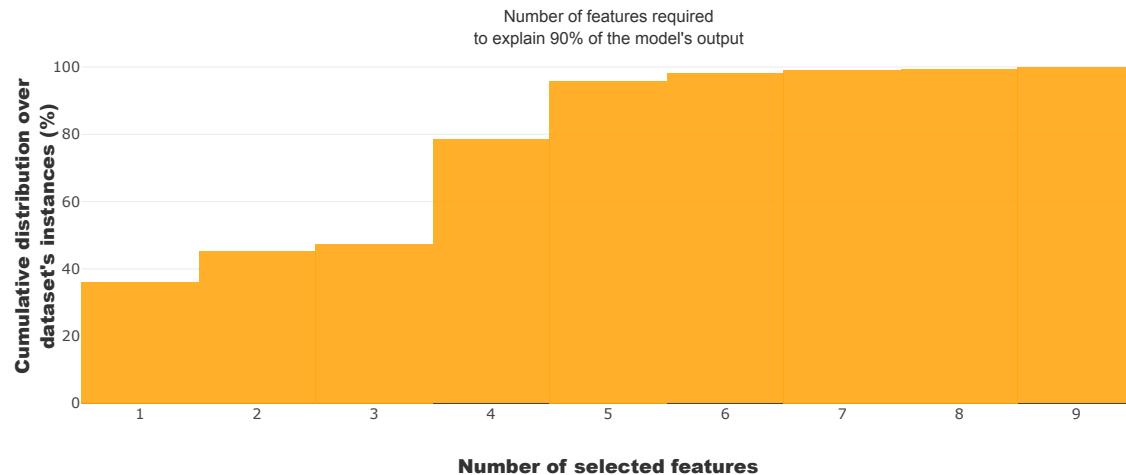
```

xpl = SmartExplainer(model=model)
xpl.compile(x=X_test, contributions=kercontribution)
img=xpl.plot.compacity_plot()
img.show()

```

## Compacity o

How many variables are enough



```
# img.write_image('/content/drive/My Drive/DL4H_Sp24_Final_Project/compactker.png')
```

```
xpl = SmartExplainer(model=model)
xpl.compile(x=X_test, contributions=trecontrib)
img=xpl.plot.compacity_plot()
img.show()
```

## Compacity o

How many variables are enough

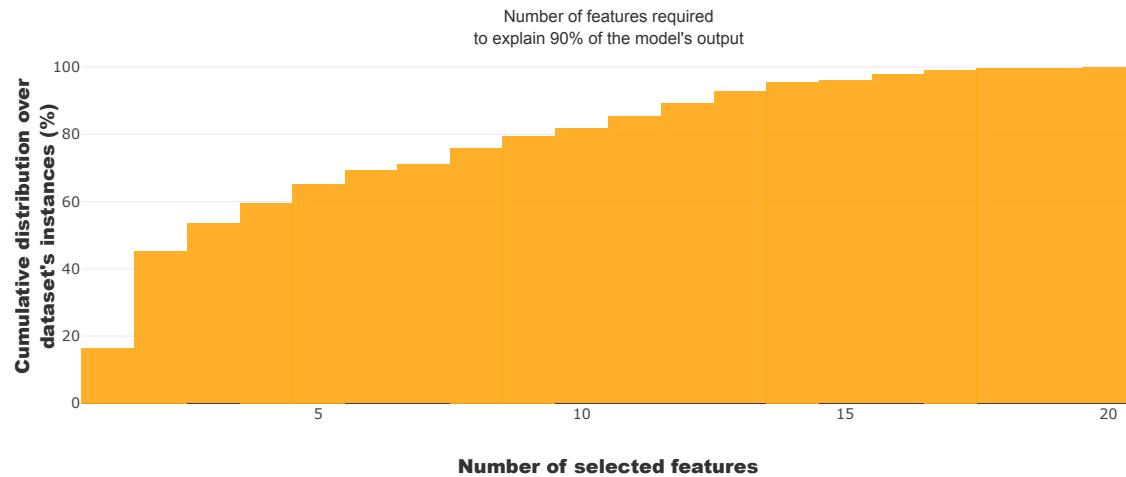


```
# img.write_image('/content/drive/My Drive/DL4H_Sp24_Final_Project/compacttree.png')
```

```
xpl = SmartExplainer(model=model)
xpl.compile(x=X_test, contributions=limecontrib)
img=xpl.plot.compacity_plot()
img.show()
```

## Compacity o

How many variables are enough



```
# img.write_image('/content/drive/My Drive/DL4H_Sp24_Final_Project/compactlime.png')
```

```
xpl = SmartExplainer(model=model)
xpl.compile(x=X_test, contributions=samcontrib)
img=xpl.plot.compacity_plot()
img.show()
```

## Compacity o

How many variables are enough



```
# img.write_image('/content/drive/My Drive/DL4H_Sp24_Final_Project/compactsampling.png')
```

```
xpl = SmartExplainer(model=model)
xpl.compile(x=X_test, contributions=ticontrib)
img=xpl.plot.compacity_plot()
img.show()
```

## Compacity o

How many variables are enough

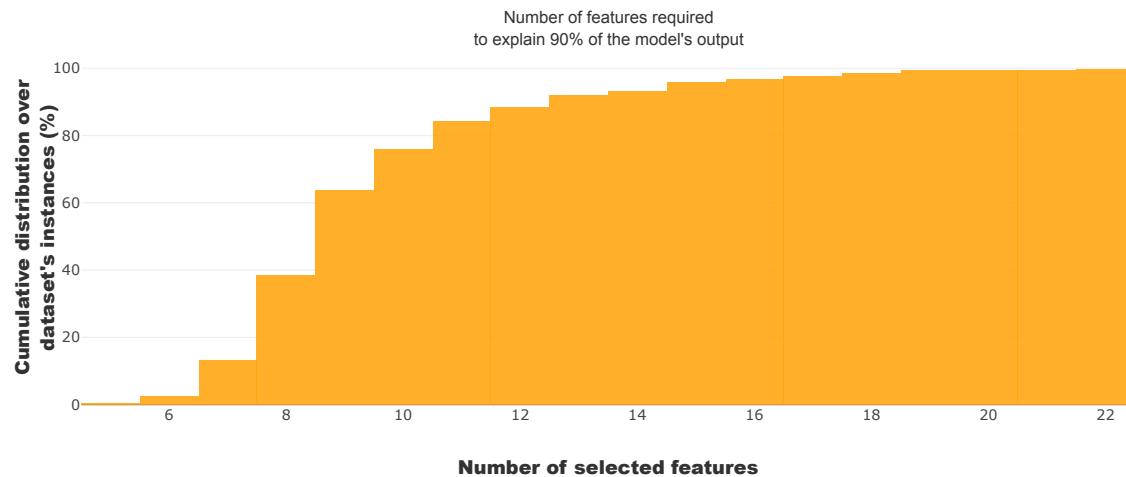


```
# img.write_image('/content/drive/My Drive/DL4H_Sp24_Final_Project/compactti.png')
```

```
xpl = SmartExplainer(model=model)
xpl.compile(x=X_test, contributions=dicecontrib)
img=xpl.plot.compacity_plot()
img.show()
```

## Compacity o

How many variables are enough



```
# img.write_image('/content/drive/My Drive/DL4H_Sp24_Final_Project/compactdice.png')
```

## ✓ Stability

```

from sklearn.preprocessing import normalize

def _compute_distance(x1, x2, mean_vector, epsilon=0.0000001):
    """
    Compute distances between data points by using L1 on normalized data : sum(abs(x1-x2)/(mean_vector+epsilon))
    Parameters
    -----
    x1 : array
        First vector
    x2 : array
        Second vector
    mean_vector : array
        Each value of this vector is the std.dev for each feature in dataset
    Returns
    -----
    diff : float
        Returns :math:`\sum(\frac{|x1-x2|}{mean\_vector+epsilon})`
    """
    diff = np.sum(np.abs(x1 - x2) / (mean_vector + epsilon))
    return diff

def _compute_similarities(instance, dataset):
    """
    Compute pairwise distances between an instance and all other data points
    Parameters
    -----
    instance : 1D array
        Reference data point
    dataset : 2D array
        Entire dataset used to identify neighbors
    Returns
    -----
    similarity_distance : array
        V[j] == distance between actual instance and instance j
    """
    mean_vector = np.array(dataset, dtype=np.float32).std(axis=0)
    similarity_distance = np.zeros(dataset.shape[0])

    for j in range(0, dataset.shape[0]):
        # Calculate distance between point and instance j
        dist = _compute_distance(instance, dataset[j], mean_vector)
        similarity_distance[j] = dist

    return similarity_distance

def _get_radius(dataset, n_neighbors, sample_size=50, percentile=95):
    """
    Calculate the maximum allowed distance between points to be considered as neighbors
    Parameters
    -----
    dataset : DataFrame
        Pool to sample from and calculate a radius
    n_neighbors : int
        Maximum number of neighbors considered per instance
    sample_size : int, optional
        Number of data points to sample from dataset, by default 500
    percentile : int, optional
        Percentile used to calculate the distance threshold, by default 95
    Returns
    -----
    radius : float
        Distance threshold
    """
    # Select 500 points max to sample
    size = min([dataset.shape[0], sample_size])
    # Randomly sample points from dataset
    sampled_instances = dataset[np.random.randint(0, dataset.shape[0], size), :]
    # Define normalization vector
    mean_vector = np.array(dataset, dtype=np.float32).std(axis=0)
    # Initialize the similarity matrix
    similarity_distance = np.zeros((size, size))
    # Calculate pairwise distance between instances
    for i in range(size):
        for j in range(i, size):
            dist = _compute_distance(sampled_instances[i], sampled_instances[j], mean_vector)
            similarity_distance[i, j] = dist
            similarity_distance[j, i] = dist
    # Select top n_neighbors
    ordered_X = np.sort(similarity_distance)[:, 1:n_neighbors + 1]
    # Select the value of the distance that captures XX% of all distances (percentile)
    return np.percentile(ordered_X.flatten(), percentile)

```



```

def find_neighbors(selection, dataset, model, mode, n_neighbors=30):
    """
    For each instance, select neighbors based on 3 criteria:
    1. First pick top N closest neighbors (L1 Norm + st. dev normalization)
    2. Filter neighbors whose model output is too different from instance (see condition below)
    3. Filter neighbors whose distance is too big compared to a certain threshold
    Parameters
    -----
    selection : list
        Indices of rows to be displayed on the stability plot
    dataset : DataFrame
        Entire dataset used to identify neighbors
    model : model object
        ML model
    mode : str
        "classification" or "regression"
    n_neighbors : int, optional
        Top N neighbors initially allowed, by default 10
    Returns
    -----
    all_neighbors : list of 2D arrays
        Wrap all instances with corresponding neighbors in a list with length (#instances).
        Each array has shape (#neighbors, #features) where #neighbors includes the instance itself.
    """
    instances = dataset.loc[selection].values

    all_neighbors = np.empty((0, instances.shape[1] + 1), float)
    """Filter 1 : Pick top N closest neighbors"""
    for instance in instances:
        c = _compute_similarities(instance, dataset.values)
        # Pick indices of the closest neighbors (and include instance itself)
        neighbors_indices = np.argsort(c)[: n_neighbors + 1]
        # Return instance with its neighbors
        neighbors = dataset.values[neighbors_indices]
        # Add distance column
        neighbors = np.append(neighbors, c[neighbors_indices].reshape(n_neighbors + 1, 1), axis=1)
        all_neighbors = np.append(all_neighbors, neighbors, axis=0)

    # Calculate predictions for all instances and corresponding neighbors
    if mode == "regression":
        # For XGB it is necessary to add columns in df, otherwise columns mismatch
        predictions = model.predict(pd.DataFrame(all_neighbors[:, :-1], columns=dataset.columns))
    elif mode == "classification":
        predictions = model.predict_proba(pd.DataFrame(all_neighbors[:, :-1], columns=dataset.columns))[:, 1]

    # Add prediction column
    all_neighbors = np.append(all_neighbors, predictions.reshape(all_neighbors.shape[0], 1), axis=1)
    # Split back into original chunks (1 chunk = instance + neighbors)
    all_neighbors = np.split(all_neighbors, instances.shape[0])

    """Filter 2 : neighbors with similar blackbox output"""
    # Remove points if prediction is far away from instance prediction
    if mode == "regression":
        # Trick : use enumerate to allow the modification directly on the iterator
        for i, neighbors in enumerate(all_neighbors):
            all_neighbors[i] = neighbors[abs(neighbors[:, -1] - neighbors[0, -1]) < 0.1 * abs(neighbors[0, -1])]
    elif mode == "classification":
        for i, neighbors in enumerate(all_neighbors):
            all_neighbors[i] = neighbors[abs(neighbors[:, -1] - neighbors[0, -1]) < 0.1]

    """Filter 3 : neighbors below a distance threshold"""
    # Remove points if distance is bigger than radius
    radius = _get_radius(dataset.values, n_neighbors)

    for i, neighbors in enumerate(all_neighbors):
        # -2 indicates the distance column
        all_neighbors[i] = neighbors[neighbors[:, -2] < radius]
    return all_neighbors

def shap_neighbors(instance, x_encoded, contributions, mode):
    """
    For an instance and corresponding neighbors, calculate various
    metrics (described below) that are useful to evaluate local stability
    Parameters
    -----
    instance : 2D array
        Instance + neighbours with corresponding features
    x_encoded : DataFrame
        Entire dataset used to identify neighbors
    contributions : DataFrame
        Calculated contribution values for the dataset
    Returns
    -----
    norm_shap_values : array
        Normalized SHAP values (with corresponding sign) of instance and its neighbors
    average_diff : array
    """

```



```

Variability (stddev / mean) of normalized SHAP values (using L1) across neighbors for each feature
norm_abs_shap_values[0, :] : array
    Normalized absolute SHAP value of the instance
"""

# Extract SHAP values for instance and neighbors
# :-2 indicates that two columns are disregarded : distance to instance and model output
ind = pd.merge(x_encoded.reset_index(), pd.DataFrame(instance[:, :-2], columns=x_encoded.columns), how='inner')\
    .set_index(x_encoded.index.name if x_encoded.index.name is not None else 'index').index
# If classification, select contributions of one class only
if mode == "classification" and len(contributions) == 2:
    contributions = contributions[1]
shap_values = contributions.loc[ind]
# For neighbors comparison, the sign of SHAP values is taken into account
norm_shap_values = normalize(shap_values, axis=1, norm="l1")
# But not for the average impact of the features across the dataset
norm_abs_shap_values = normalize(np.abs(shap_values), axis=1, norm="l1")
# Compute the average difference between the instance and its neighbors
# And replace NaN with 0
average_diff = np.divide(norm_shap_values.std(axis=0), norm_abs_shap_values.mean(axis=0),
                        out=np.zeros(norm_abs_shap_values.shape[1]),
                        where=norm_abs_shap_values.mean(axis=0) != 0)

return norm_shap_values, average_diff, norm_abs_shap_values[0, :]

def get_distance(selection, contributions, mode, nb_features):
"""
Determine how close we get to the output with all features by using only a subset of them
Parameters
-----
selection : list
    Indices of rows to be displayed on the stability plot
contributions : DataFrame
    Calculated contribution values for the dataset
mode : str
    "classification" or "regression"
nb_features : int, optional
    Number of features used, by default 5
Returns
-----
distance : array
    List of distances for each instance by using top selected features (ex: np.array([0.12, 0.16...])). 

* For regression:
    * normalized distance between the output of current model and output of full model
    * For classification:
        * distance between probability outputs (absolute value)
"""

if mode == "classification" and len(contributions) == 2:
    contributions = contributions[1]
assert nb_features <= contributions.shape[1]

contributions = contributions.loc[selection].values
top_features = np.array([sorted(row, key=abs, reverse=True) for row in contributions])[:, :nb_features]
output_top_features = np.sum(top_features[:, :, :], axis=1)
output_all_features = np.sum(contributions[:, :, :], axis=1)

if mode == "regression":
    distance = abs(output_top_features - output_all_features) / abs(output_all_features)
elif mode == "classification":
    distance = abs(output_top_features - output_all_features)
return distance

def compute_features_stability(case, x, selection, contributions):
"""
For a selection of instances, compute features stability metrics used in
methods `local_neighbors_plot` and `local_stability_plot`.
- If selection is a single instance, the method returns the (normalized) contribution values
of instance and corresponding neighbors.
- If selection represents multiple instances, the method returns the average (normalized) contribution values
of instances and neighbors (=amplitude), as well as the variability of those values in the neighborhood (=variability)
Parameters
-----
selection: list
    Indices of rows to be displayed on the stability plot
Returns
-----
Dictionary
    Values that will be displayed on the graph. Keys are "amplitude", "variability" and "norm_shap"
"""

#if (case == "classification") and (len(self._classes) > 2):
#    raise AssertionError("Multi-class classification is not supported")
x_encoded=x

```

```

x_init=x
all_neighbors = find_neighbors(selection, x_encoded, model, case)

# Check if entry is a single instance or not
if len(selection) == 1:
    # Compute explanations for instance and neighbors
    norm_shap, _, _ = shap_neighbors(all_neighbors[0], x_encoded, contributions, case)
    local_neighbors = {"norm_shap": norm_shap}
    return local_neighbors
else:
    numb_expl = len(selection)
    amplitude = np.zeros((numb_expl, x_init.shape[1]))
    variability = np.zeros((numb_expl, x_init.shape[1]))
    # For each instance (+ neighbors), compute explanation
    for i in range(numb_expl):
        (_, variability[i, :], amplitude[i, :]) = shap_neighbors(all_neighbors[i], x_encoded, contributions, case)
    features_stability = {"variability": variability, "amplitude": amplitude}
    return features_stability

features=list(X_test.columns)

frames=[]
for weight in weights:
    #fs= compute_features_stability (case="classification", x=X_test, selection=list(range(0, len(X_test))), contributions=weight)
    fs= compute_features_stability (case="classification", x=X_test, selection=[instance], contributions=weight)
    frames.append(fs)

```

## ▼ One Instance

```

colors = ['tab:red', 'tab:blue', 'tab:green', 'tab:pink', 'tab:olive', 'tab:orange', 'tab:gray']

for j in range(len(features)):
    fig, axes = plt.subplots(1, 7, figsize=(12, 2), sharey=True, dpi=100)
    t=0

    for fg, fs in enumerate(frames):
        am=[]

        for i in range(len(fs['norm_shap'])):
            am.append(round(fs['norm_shap'][i][j], 2)) # i INSTANCE j Feature
        sns.distplot(am, ax=axes[fg], color=colors[t], xlabel=methods[t])
        t=t+1
        axes[fg].set_ylabel(features[j])
    # plt.savefig(root+'/'+str(var)+str(instance)+str(features[j])[:10]+'.png', bbox_inches='tight', dpi=300)
    plt.show()

```