De_Guzman_Hands_on_Activity_11_2_Classification_using_Logistic_Reg

April 28, 2024

1 Hands-on Activity 11.2 Classification using Logistic Regression

1.1 Objective(s):

- This activity aims to demonstrate how to apply simple linear regression analysis to solve regression problem

1.2 Intended Learning Outcomes (ILOs):

- Demonstrate how to solve classification problems using Logistic Regression
- Use the logistic regression model to perform classification

1.3 Resources:

- Jupyter Notebook

1.4 Dataset:

- https://archive.ics.uci.edu/ml/datasets/Cervical+cancer+%28Risk+Factors%29

1.5 Submission Requirements:

- PDF containing initial EDA and Data Wrangling
- PDF showing demonstration of simple linear regression.
- Submit a link to the colab file through the comment section.

1.6 Procedure:

1.6.1 Setup

```
[1]: import pandas as pd
     import numpy as np
     import matplotlib.pyplot as plt
     import seaborn as sns
     from scipy import stats

     %matplotlib inline
```

[2]:

```python
import warnings
warnings.filterwarnings('ignore')
```

[3]:

```
!pip install ucimlrepo
```

```
Collecting ucimlrepo
  Downloading ucimlrepo-0.0.6-py3-none-any.whl (8.0 kB)
Installing collected packages: ucimlrepo
Successfully installed ucimlrepo-0.0.6
```

[4]:

```python
from ucimlrepo import fetch_ucirepo

# fetch dataset
cervical_cancer_risk_factors = fetch_ucirepo(id=383)

# data (as pandas dataframes)
ccrf_df = cervical_cancer_risk_factors.data.features

# metadata
print(cervical_cancer_risk_factors.metadata)

# variable information
print(cervical_cancer_risk_factors.variables)
```

```
{'uci_id': 383, 'name': 'Cervical Cancer (Risk Factors)', 'repository_url':
'https://archive.ics.uci.edu/dataset/383/cervical+cancer+risk+factors',
'data_url': 'https://archive.ics.uci.edu/static/public/383/data.csv',
'abstract': 'This dataset focuses on the prediction of indicators/diagnosis of
cervical cancer. The features cover demographic information, habits, and
historic medical records.', 'area': 'Health and Medicine', 'tasks':
['Classification'], 'characteristics': ['Multivariate'], 'num_instances': 858,
'num_features': 36, 'feature_types': ['Integer', 'Real'], 'demographics':
['Age', 'Other'], 'target_col': None, 'index_col': None, 'has_missing_values':
'yes', 'missing_values_symbol': 'NaN', 'year_of_dataset_creation': 2017,
'last_updated': 'Sun Mar 10 2024', 'dataset_doi': '10.24432/C5Z310', 'creators':
['Kelwin Fernandes', 'Jaime Cardoso', 'Jessica Fernandes'], 'intro_paper':
{'title': 'Transfer Learning with Partial Observability Applied to Cervical
Cancer Screening', 'authors': 'Kelwin Fernandes, Jaime S. Cardoso, Jessica C.
Fernandes', 'published_in': 'Iberian Conference on Pattern Recognition and Image
Analysis', 'year': 2017, 'url': 'https://www.semanticscholar.org/paper/Transfer-
Learning-with-Partial-Observability-to-Fernandes-
Cardoso/1c02438ba4dfa775399ba414508e9cd335b69012', 'doi': None},
'additional_info': {'summary': "The dataset was collected at 'Hospital
Universitario de Caracas' in Caracas, Venezuela. The dataset comprises
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).", 'purpose': None, 'funded_by': None,
'instances_represent': None, 'recommended_data_splits': None, 'sensitive_data':
```

```
None, 'preprocessing_description': None, 'variable_info': '(int) Age\r\n(int)
Number of sexual partners\r\n(int) First sexual intercourse (age)\r\n(int) Num
of pregnancies\r\n(bool) Smokes\r\n(bool) Smokes (years)\r\n(bool) Smokes
(packs/year)\r\n(bool) Hormonal Contraceptives\r\n(int) Hormonal Contraceptives
(years)\r\n(bool) IUD\r\n(int) IUD (years)\r\n(bool) STDs\r\n(int) STDs
(number)\r\n(bool) STDs:condylomatosis\r\n(bool) STDs:cervical
condylomatosis\r\n(bool) STDs:vaginal condylomatosis\r\n(bool) STDs:vulvo-
perineal condylomatosis\r\n(bool) STDs:syphilis\r\n(bool) STDs:pelvic
inflammatory disease\r\n(bool) STDs:genital herpes\r\n(bool) STDs:molluscum
contagiosum\r\n(bool) STDs:AIDS\r\n(bool) STDs:HIV\r\n(bool) STDs:Hepatitis
B\r\n(bool) STDs:HPV\r\n(int) STDs: Number of diagnosis\r\n(int) STDs: Time
since first diagnosis\r\n(int) STDs: Time since last diagnosis\r\n(bool)
Dx:Cancer\r\n(bool) Dx:CIN\r\n(bool) Dx:HPV\r\n(bool) Dx\r\n(bool) Hinselmann:
target variable\r\n(bool) Schiller: target variable\r\n(bool) Cytology: target
variable\r\n(bool) Biopsy: target variable', 'citation': None}}
                                  name    role       type demographic  \
0                                  Age Feature     Integer         Age
1            Number of sexual partners Feature  Continuous       Other
2             First sexual intercourse Feature  Continuous        None
3                   Num of pregnancies Feature  Continuous        None
4                               Smokes Feature  Continuous        None
5                       Smokes (years) Feature  Continuous        None
6                  Smokes (packs/year) Feature  Continuous        None
7              Hormonal Contraceptives Feature  Continuous        None
8      Hormonal Contraceptives (years) Feature  Continuous        None
9                                  IUD Feature  Continuous        None
10                         IUD (years) Feature  Continuous        None
11                                STDs Feature  Continuous        None
12                       STDs (number) Feature  Continuous        None
13                 STDs:condylomatosis Feature  Continuous        None
14        STDs:cervical condylomatosis Feature  Continuous        None
15         STDs:vaginal condylomatosis Feature  Continuous        None
16  STDs:vulvo-perineal condylomatosis Feature  Continuous        None
17                       STDs:syphilis Feature  Continuous        None
18    STDs:pelvic inflammatory disease Feature  Continuous        None
19                 STDs:genital herpes Feature  Continuous        None
20          STDs:molluscum contagiosum Feature  Continuous        None
21                           STDs:AIDS Feature  Continuous        None
22                            STDs:HIV Feature  Continuous        None
23                    STDs:Hepatitis B Feature  Continuous        None
24                            STDs:HPV Feature  Continuous        None
25           STDs: Number of diagnosis Feature     Integer        None
26    STDs: Time since first diagnosis Feature  Continuous        None
27     STDs: Time since last diagnosis Feature  Continuous        None
28                           Dx:Cancer Feature     Integer        None
29                              Dx:CIN Feature     Integer        None
30                              Dx:HPV Feature     Integer        None
31                                  Dx Feature     Integer        None
```

```
32                          Hinselmann  Feature     Integer        None
33                            Schiller  Feature     Integer        None
34                            Citology  Feature     Integer        None
35                              Biopsy  Feature     Integer        None

   description units missing_values
0         None  None             no
1         None  None            yes
2         None  None            yes
3         None  None            yes
4         None  None            yes
5         None  None            yes
6         None  None            yes
7         None  None            yes
8         None  None            yes
9         None  None            yes
10        None  None            yes
11        None  None            yes
12        None  None            yes
13        None  None            yes
14        None  None            yes
15        None  None            yes
16        None  None            yes
17        None  None            yes
18        None  None            yes
19        None  None            yes
20        None  None            yes
21        None  None            yes
22        None  None            yes
23        None  None            yes
24        None  None            yes
25        None  None             no
26        None  None            yes
27        None  None            yes
28        None  None             no
29        None  None             no
30        None  None             no
31        None  None             no
32        None  None             no
33        None  None             no
34        None  None             no
35        None  None             no
```

1.6.2 Data Wrangling and Cleaning

[5]:

```
# Checking the shape of the dataset
ccrf_df.shape
```

[5]:

```
(858, 36)
```

[6]:

```
# Checking general information
ccrf_df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 858 entries, 0 to 857
Data columns (total 36 columns):
 #   Column                              Non-Null Count  Dtype
---  ------                              --------------  -----
 0   Age                                 858 non-null    int64
 1   Number of sexual partners           832 non-null    float64
 2   First sexual intercourse            851 non-null    float64
 3   Num of pregnancies                  802 non-null    float64
 4   Smokes                              845 non-null    float64
 5   Smokes (years)                      845 non-null    float64
 6   Smokes (packs/year)                 845 non-null    float64
 7   Hormonal Contraceptives             750 non-null    float64
 8   Hormonal Contraceptives (years)     750 non-null    float64
 9   IUD                                 741 non-null    float64
 10  IUD (years)                         741 non-null    float64
 11  STDs                                753 non-null    float64
 12  STDs (number)                       753 non-null    float64
 13  STDs:condylomatosis                 753 non-null    float64
 14  STDs:cervical condylomatosis        753 non-null    float64
 15  STDs:vaginal condylomatosis         753 non-null    float64
 16  STDs:vulvo-perineal condylomatosis  753 non-null    float64
 17  STDs:syphilis                       753 non-null    float64
 18  STDs:pelvic inflammatory disease    753 non-null    float64
 19  STDs:genital herpes                 753 non-null    float64
 20  STDs:molluscum contagiosum          753 non-null    float64
 21  STDs:AIDS                           753 non-null    float64
 22  STDs:HIV                            753 non-null    float64
 23  STDs:Hepatitis B                    753 non-null    float64
 24  STDs:HPV                            753 non-null    float64
 25  STDs: Number of diagnosis           858 non-null    int64
 26  STDs: Time since first diagnosis    71 non-null     float64
 27  STDs: Time since last diagnosis     71 non-null     float64
 28  Dx:Cancer                           858 non-null    int64
 29  Dx:CIN                              858 non-null    int64
 30  Dx:HPV                              858 non-null    int64
 31  Dx                                  858 non-null    int64
 32  Hinselmann                          858 non-null    int64
 33   Schiller                                  858 non-null    int64
 34   Citology                                  858 non-null    int64
 35   Biopsy                                    858 non-null    int64
dtypes: float64(26), int64(10)
memory usage: 241.4 KB
```

[7]:

```
# Dropping unusable columns
ccrf_df.drop(columns=["STDs: Time since first diagnosis","STDs: Time since last␣
 ↪diagnosis"], inplace=True)
```

[8]:

```
# Dropping Age records with only 1 row in the dataset
counts = ccrf_df['Age'].value_counts().sort_values()

for i in list(counts.index):
  if counts[i] < 2:
    ccrf_df.drop(ccrf_df[ccrf_df['Age'] == i].index, axis=0, inplace=True)
```

[9]:

```
# Listing all NaN columns and filtering out the boolean-like datatypes
nan_cols = list(ccrf_df[ccrf_df.columns[ccrf_df.isna().any()]].columns)

for i in nan_cols:
  if len(list(ccrf_df[i].unique())) <= 3:
    print(i)
    print(list(ccrf_df[i].unique()))
```

```
Smokes
[0.0, 1.0, nan]
Hormonal Contraceptives
[0.0, 1.0, nan]
IUD
[0.0, 1.0, nan]
STDs
[0.0, 1.0, nan]
STDs:condylomatosis
[0.0, 1.0, nan]
STDs:cervical condylomatosis
[0.0, nan]
STDs:vaginal condylomatosis
[0.0, nan, 1.0]
STDs:vulvo-perineal condylomatosis
[0.0, 1.0, nan]
STDs:syphilis
[0.0, 1.0, nan]
STDs:pelvic inflammatory disease
[0.0, nan, 1.0]
STDs:genital herpes
[0.0, nan, 1.0]
STDs:molluscum contagiosum
```

```
[0.0, nan, 1.0]
STDs:AIDS
[0.0, nan]
STDs:HIV
[0.0, 1.0, nan]
STDs:Hepatitis B
[0.0, nan, 1.0]
STDs:HPV
[0.0, nan, 1.0]
```

[10]:

```
# Dropping columns with only 0 and NaN values
ccrf_df.drop(['STDs:cervical condylomatosis', 'STDs:AIDS'], axis=1,␣
 ↪inplace=True)
```

[11]:

```
# Relisting all NaN columns and separating the boolean-like datatypes
nan_cols = list(ccrf_df[ccrf_df.columns[ccrf_df.isna().any()]].columns)

nan_mean = []

for i in nan_cols:
  if len(list(ccrf_df[i].unique())) <= 3:
    print(i)
    print(list(ccrf_df[i].unique()))
  else:
    nan_mean.append(i)
```

```
Smokes
[0.0, 1.0, nan]
Hormonal Contraceptives
[0.0, 1.0, nan]
IUD
[0.0, 1.0, nan]
STDs
[0.0, 1.0, nan]
STDs:condylomatosis
[0.0, 1.0, nan]
STDs:vaginal condylomatosis
[0.0, nan, 1.0]
STDs:vulvo-perineal condylomatosis
[0.0, 1.0, nan]
STDs:syphilis
[0.0, 1.0, nan]
STDs:pelvic inflammatory disease
[0.0, nan, 1.0]
STDs:genital herpes
[0.0, nan, 1.0]
STDs:molluscum contagiosum
[0.0, nan, 1.0]
```

```
STDs:HIV
[0.0, 1.0, nan]
STDs:Hepatitis B
[0.0, nan, 1.0]
STDs:HPV
[0.0, nan, 1.0]
```

[12]:

```
# Checking the frequency of records for each non-boolean column
for i in nan_mean:
  print(ccrf_df[i].value_counts())
```

```
Number of sexual partners
2.0     268
3.0     206
1.0     205
4.0      78
5.0      44
6.0       9
7.0       7
8.0       4
15.0      1
10.0      1
28.0      1
9.0       1
Name: count, dtype: int64
First sexual intercourse
15.0    163
17.0    148
18.0    137
16.0    120
14.0     79
19.0     60
20.0     36
13.0     23
21.0     20
23.0      9
22.0      9
26.0      7
12.0      6
27.0      6
24.0      6
29.0      5
28.0      3
11.0      2
25.0      2
10.0      2
32.0      1
Name: count, dtype: int64
```

```
Num of pregnancies
1.0     270
2.0     240
3.0     138
4.0      74
5.0      34
6.0      17
0.0      15
7.0       5
8.0       2
10.0      1
Name: count, dtype: int64
Smokes (years)
0.000000     717
1.266973      15
5.000000       9
9.000000       9
1.000000       8
3.000000       7
2.000000       7
8.000000       6
7.000000       6
16.000000      6
11.000000      5
4.000000       5
10.000000      5
14.000000      4
15.000000      4
6.000000       4
13.000000      3
0.500000       3
19.000000      3
12.000000      3
22.000000      2
37.000000      1
21.000000      1
18.000000      1
32.000000      1
28.000000      1
20.000000      1
0.160000       1
Name: count, dtype: int64
Smokes (packs/year)
0.000000     717
0.513202      17
1.000000       6
3.000000       5
2.000000       4
```

```
            …
37.000000      1
2.250000       1
0.003000       1
0.450000       1
0.300000       1
Name: count, Length: 61, dtype: int64
Hormonal Contraceptives (years)
0.000000     264
1.000000      77
0.250000      41
2.000000      40
3.000000      39
5.000000      33
0.080000      25
0.500000      25
6.000000      24
4.000000      22
7.000000      21
8.000000      18
0.160000      16
9.000000      12
10.000000     11
0.330000       9
0.420000       8
0.750000       7
15.000000      6
0.580000       6
0.660000       6
12.000000      4
20.000000      3
1.500000       3
0.670000       2
13.000000      2
11.000000      2
2.282201       2
14.000000      2
19.000000      2
16.000000      2
22.000000      1
2.500000       1
4.500000       1
6.500000       1
0.170000       1
3.500000       1
0.410000       1
30.000000      1
17.000000      1
```

```
Name: count, dtype: int64
IUD (years)
0.00     653
3.00      11
2.00      10
5.00       9
1.00       8
8.00       7
7.00       6
6.00       5
4.00       5
11.00      3
0.50       2
0.08       2
0.91       1
0.33       1
9.00       1
0.16       1
1.50       1
0.25       1
12.00      1
15.00      1
10.00      1
17.00      1
19.00      1
0.58       1
0.17       1
Name: count, dtype: int64
STDs (number)
0.0    667
2.0     37
1.0     34
3.0      7
4.0      1
Name: count, dtype: int64
```

[13]:

```
# Since the distribution is more spread out between the high frequency records
# We will be using mean to fill the missing values
mean_cols = ['Number of sexual partners', 'First sexual intercourse', 'Num of␣
 ↪pregnancies']

for i in mean_cols:
  nan_mean.remove(i)

for i in mean_cols:
  ave = ccrf_df[ccrf_df[i].isnull()]['Age'].apply(
      lambda x: ccrf_df[ccrf_df['Age'] == x][i].mean()
  )
  ccrf_df[i].fillna(ave, inplace=True)
  ccrf_df[i] = ccrf_df[i].astype('int64')
  nan_cols.remove(i)
```

[14]:

```
# For the boolean-like values, we will be using mode instead
for i in nan_mean:
  mod = ccrf_df[ccrf_df[i].isnull()]['Age'].apply(
      lambda x: ccrf_df[ccrf_df['Age'] == x][i].mode()
  )
  ccrf_df[i].fillna(mod[0], inplace=True)
```

[15]:

```
for i in nan_mean:
  nan_cols.remove(i)

for i in nan_cols:
  mod = ccrf_df[ccrf_df[i].isnull()]['Age'].apply(
      lambda x: ccrf_df[ccrf_df['Age'] == x][i].mode()
  )
  ccrf_df[i].fillna(mod[0], inplace=True)
```

[16]:

```
# Rechecking the DataFrame
ccrf_df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Index: 851 entries, 0 to 857
Data columns (total 32 columns):
 #   Column                              Non-Null Count  Dtype
---  ------                              --------------  -----
 0   Age                                 851 non-null    int64
 1   Number of sexual partners           851 non-null    int64
 2   First sexual intercourse            851 non-null    int64
 3   Num of pregnancies                  851 non-null    int64
 4   Smokes                              851 non-null    float64
 5   Smokes (years)                      851 non-null    float64
 6   Smokes (packs/year)                 851 non-null    float64
 7   Hormonal Contraceptives             851 non-null    float64
 8   Hormonal Contraceptives (years)     851 non-null    float64
 9   IUD                                 851 non-null    float64
 10  IUD (years)                         851 non-null    float64
 11  STDs                                851 non-null    float64
 12  STDs (number)                       851 non-null    float64
 13  STDs:condylomatosis                 851 non-null    float64
 14  STDs:vaginal condylomatosis         851 non-null    float64
 15  STDs:vulvo-perineal condylomatosis  851 non-null    float64
 16  STDs:syphilis                       851 non-null    float64
 17  STDs:pelvic inflammatory disease    851 non-null    float64
 18  STDs:genital herpes                 851 non-null    float64
 19  STDs:molluscum contagiosum          851 non-null    float64
 20  STDs:HIV                            851 non-null    float64
 21  STDs:Hepatitis B                    851 non-null    float64
 22  STDs:HPV                            851 non-null    float64
 23  STDs: Number of diagnosis           851 non-null    int64
 24  Dx:Cancer                           851 non-null    int64
 25  Dx:CIN                              851 non-null    int64
 26  Dx:HPV                              851 non-null    int64
 27  Dx                                  851 non-null    int64
 28  Hinselmann                          851 non-null    int64
 29  Schiller                            851 non-null    int64
 30  Citology                            851 non-null    int64
 31  Biopsy                              851 non-null    int64
dtypes: float64(19), int64(13)
memory usage: 219.4 KB
```

[17]:

```python
# Converting the boolean-like columns to categorical
for i in ccrf_df.columns:
  if list(ccrf_df[i].unique()) == [0.0, 1.0]:
    ccrf_df[i] = ccrf_df[i].astype('category')

ccrf_df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Index: 851 entries, 0 to 857
Data columns (total 32 columns):
 #   Column                              Non-Null Count  Dtype
---  ------                              --------------  -----
 0   Age                                 851 non-null    int64
 1   Number of sexual partners           851 non-null    int64
 2   First sexual intercourse            851 non-null    int64
 3   Num of pregnancies                  851 non-null    int64
 4   Smokes                              851 non-null    category
 5   Smokes (years)                      851 non-null    float64
 6   Smokes (packs/year)                 851 non-null    float64
 7   Hormonal Contraceptives             851 non-null    category
 8   Hormonal Contraceptives (years)     851 non-null    float64
 9   IUD                                 851 non-null    category
 10  IUD (years)                         851 non-null    float64
 11  STDs                                851 non-null    category
 12  STDs (number)                       851 non-null    float64
 13  STDs:condylomatosis                 851 non-null    category
 14  STDs:vaginal condylomatosis         851 non-null    category
 15  STDs:vulvo-perineal condylomatosis  851 non-null    category
 16  STDs:syphilis                       851 non-null    category
 17  STDs:pelvic inflammatory disease    851 non-null    category
 18  STDs:genital herpes                 851 non-null    category
 19  STDs:molluscum contagiosum          851 non-null    category
 20  STDs:HIV                            851 non-null    category
 21  STDs:Hepatitis B                    851 non-null    category
 22  STDs:HPV                            851 non-null    category
 23  STDs: Number of diagnosis           851 non-null    int64
 24  Dx:Cancer                           851 non-null    category
 25  Dx:CIN                              851 non-null    category
 26  Dx:HPV                              851 non-null    category
 27  Dx                                  851 non-null    category
 28  Hinselmann                          851 non-null    category
 29  Schiller                            851 non-null    category
 30  Citology                            851 non-null    category
 31  Biopsy                              851 non-null    category
dtypes: category(22), float64(5), int64(5)
memory usage: 94.1 KB
```

1.6.3 Exploratory Data Analysis

[18]:

```
# Creating a list of columns that are categorical
cols = ccrf_df.columns

num_cols = ccrf_df._get_numeric_data().columns

cat_cols = list(set(cols)-set(num_cols))

cat_cols
```

[18]:

```
['STDs:molluscum contagiosum',
 'Dx:HPV',
 'Schiller',
 'STDs:HIV',
 'STDs:genital herpes',
 'Hormonal Contraceptives',
 'STDs:condylomatosis',
 'STDs:vaginal condylomatosis',
 'Smokes',
 'STDs:HPV',
 'STDs:vulvo-perineal condylomatosis',
 'Dx',
 'Dx:CIN',
 'STDs:Hepatitis B',
 'IUD',
 'Hinselmann',
 'STDs:syphilis',
 'STDs:pelvic inflammatory disease',
 'Dx:Cancer',
 'Biopsy',
 'Citology',
 'STDs']
```

[19]:

```
ccrf_df.corr()
```

[19]:

```
                                         Age  Number of sexual partners  \
Age                                 1.000000                   0.096134
Number of sexual partners           0.096134                   1.000000
First sexual intercourse            0.398508                  -0.148443
Num of pregnancies                  0.517323                   0.087251
Smokes                              0.039394                   0.234972
Smokes (years)                      0.173850                   0.178917
Smokes (packs/year)                 0.140875                   0.172938
Hormonal Contraceptives             0.124810                   0.018728
Hormonal Contraceptives (years)     0.329572                   0.025183
IUD                                 0.294313                   0.026920
IUD (years)                         0.226458                   0.002687
STDs                                0.036554                   0.052349
STDs (number)                       0.007109                   0.038665
STDs:condylomatosis                -0.008067                   0.034708
STDs:vaginal condylomatosis         0.012258                  -0.042824
STDs:vulvo-perineal condylomatosis -0.005716                   0.036804
STDs:syphilis                       0.023119                   0.027253
STDs:pelvic inflammatory disease    0.027830                   0.030626
STDs:genital herpes                -0.028621                  -0.031774
STDs:molluscum contagiosum          0.001776                   0.030626
STDs:HIV                            0.009678                   0.017348
STDs:Hepatitis B                   -0.028621                  -0.010974
STDs:HPV                            0.045525                   0.013904
STDs: Number of diagnosis           0.006700                   0.050313
Dx:Cancer                           0.123406                   0.022300
Dx:CIN                              0.023543                   0.020522
Dx:HPV                              0.114101                   0.027253
Dx                                  0.077433                   0.025772
Hinselmann                         -0.016784                  -0.043440
Schiller                            0.067803                  -0.011495
Citology                           -0.025413                   0.023791
Biopsy                              0.041659                  -0.002841

                                    First sexual intercourse  \
Age                                                 0.398508
Number of sexual partners                          -0.148443
First sexual intercourse                            1.000000
Num of pregnancies                                 -0.061813
Smokes                                             -0.129191
Smokes (years)                                     -0.070663
Smokes (packs/year)                                -0.057250
```

```
Hormonal Contraceptives                                 0.027286
Hormonal Contraceptives (years)                         0.032884
IUD                                                     0.003976
IUD (years)                                            -0.017582
STDs                                                   -0.003167
STDs (number)                                           0.015584
STDs:condylomatosis                                     0.033990
STDs:vaginal condylomatosis                             0.073726
STDs:vulvo-perineal condylomatosis                      0.038207
STDs:syphilis                                          -0.096574
STDs:pelvic inflammatory disease                       -0.000029
STDs:genital herpes                                     0.024522
STDs:molluscum contagiosum                             -0.012304
STDs:HIV                                               -0.008892
STDs:Hepatitis B                                        0.012247
STDs:HPV                                                0.034700
STDs: Number of diagnosis                              -0.014101
Dx:Cancer                                               0.067100
Dx:CIN                                                 -0.017514
Dx:HPV                                                  0.043718
Dx                                                      0.046541
Hinselmann                                             -0.017350
Schiller                                               -0.001775
Citology                                               -0.011714
Biopsy                                                  0.006744

                                    Num of pregnancies    Smokes  \
Age                                           0.517323  0.039394
Number of sexual partners                     0.087251  0.234972
First sexual intercourse                     -0.061813 -0.129191
Num of pregnancies                            1.000000  0.064492
Smokes                                        0.064492  1.000000
Smokes (years)                                0.131540  0.731772
Smokes (packs/year)                           0.107429  0.493729
Hormonal Contraceptives                       0.174833  0.012862
Hormonal Contraceptives (years)               0.237313  0.049817
IUD                                           0.218666 -0.065794
IUD (years)                                   0.150820 -0.046597
STDs                                          0.063663  0.113248
STDs (number)                                 0.017135  0.101894
STDs:condylomatosis                          -0.029894  0.056889
STDs:vaginal condylomatosis                   0.001458  0.070408
STDs:vulvo-perineal condylomatosis           -0.029356  0.059695
STDs:syphilis                                 0.155067  0.080456
STDs:pelvic inflammatory disease             -0.055582 -0.013964
STDs:genital herpes                          -0.030555 -0.013964
STDs:molluscum contagiosum                    0.044525 -0.013964
```

```
STDs:HIV                                      0.023975  0.057072
STDs:Hepatitis B                             -0.030555  0.084248
STDs:HPV                                     -0.025530  0.049727
STDs: Number of diagnosis                     0.046418  0.092415
Dx:Cancer                                     0.041851 -0.013080
Dx:CIN                                        0.019837 -0.039661
Dx:HPV                                        0.053769  0.010304
Dx                                            0.031295 -0.067855
Hinselmann                                    0.037163  0.020027
Schiller                                      0.066088  0.035344
Citology                                     -0.021527 -0.001751
Biopsy                                        0.032965  0.020386

                                    Smokes (years)  Smokes (packs/year)  \
Age                                       0.173850             0.140875
Number of sexual partners                 0.178917             0.172938
First sexual intercourse                 -0.070663            -0.057250
Num of pregnancies                        0.131540             0.107429
Smokes                                    0.731772             0.493729
Smokes (years)                            1.000000             0.756261
Smokes (packs/year)                       0.756261             1.000000
Hormonal Contraceptives                   0.022803             0.013656
Hormonal Contraceptives (years)           0.076611             0.050545
IUD                                      -0.000894             0.002299
IUD (years)                               0.005594             0.010524
STDs                                      0.099750             0.029432
STDs (number)                             0.098615             0.030416
STDs:condylomatosis                       0.049766             0.007707
STDs:vaginal condylomatosis               0.122828             0.042018
STDs:vulvo-perineal condylomatosis        0.051908             0.008870
STDs:syphilis                             0.016946            -0.003697
STDs:pelvic inflammatory disease         -0.010219            -0.006895
STDs:genital herpes                      -0.010219            -0.006895
STDs:molluscum contagiosum               -0.010219            -0.006895
STDs:HIV                                  0.096700             0.054125
STDs:Hepatitis B                          0.106008             0.101475
STDs:HPV                                  0.055122            -0.008004
STDs: Number of diagnosis                 0.087610             0.030078
Dx:Cancer                                 0.058383             0.107425
Dx:CIN                                   -0.029023            -0.019582
Dx:HPV                                    0.061080             0.109316
Dx                                       -0.049654            -0.033502
Hinselmann                                0.027587             0.018572
Schiller                                  0.045542             0.012742
Citology                                 -0.002630             0.005480
Biopsy                                    0.030026             0.019554
```

```
                                    Hormonal Contraceptives  \
Age                                                0.124810
Number of sexual partners                          0.018728
First sexual intercourse                           0.027286
Num of pregnancies                                 0.174833
Smokes                                             0.012862
Smokes (years)                                     0.022803
Smokes (packs/year)                                0.013656
Hormonal Contraceptives                            1.000000
Hormonal Contraceptives (years)                    0.396248
IUD                                                0.033442
IUD (years)                                       -0.036943
STDs                                              -0.028755
STDs (number)                                     -0.038108
STDs:condylomatosis                               -0.013032
STDs:vaginal condylomatosis                       -0.059996
STDs:vulvo-perineal condylomatosis                -0.017002
STDs:syphilis                                      0.001218
STDs:pelvic inflammatory disease                   0.024468
STDs:genital herpes                                0.024468
STDs:molluscum contagiosum                        -0.048083
STDs:HIV                                          -0.067878
STDs:Hepatitis B                                  -0.048083
STDs:HPV                                           0.034623
STDs: Number of diagnosis                         -0.046731
Dx:Cancer                                          0.018492
Dx:CIN                                             0.017978
Dx:HPV                                             0.035766
Dx                                                 0.011599
Hinselmann                                         0.031303
Schiller                                          -0.009485
Citology                                          -0.039697
Biopsy                                            -0.001293

                                    Hormonal Contraceptives (years)       IUD  \
Age                                                        0.329572  0.294313
Number of sexual partners                                  0.025183  0.026920
First sexual intercourse                                   0.032884  0.003976
Num of pregnancies                                         0.237313  0.218666
Smokes                                                     0.049817 -0.065794
Smokes (years)                                             0.076611 -0.000894
Smokes (packs/year)                                        0.050545  0.002299
Hormonal Contraceptives                                    0.396248  0.033442
Hormonal Contraceptives (years)                            1.000000  0.164459
IUD                                                        0.164459  1.000000
IUD (years)                                                0.019166  0.740203
STDs                                                       0.004775  0.058620
STDs (number)                                            0.000246  0.059850
STDs:condylomatosis                                      0.014953  0.084224
STDs:vaginal condylomatosis                             -0.033394  0.035316
STDs:vulvo-perineal condylomatosis                       0.016604  0.068826
STDs:syphilis                                            0.002401 -0.020799
STDs:pelvic inflammatory disease                        -0.011897 -0.011276
STDs:genital herpes                                     -0.016667 -0.011276
STDs:molluscum contagiosum                              -0.019053 -0.011276
STDs:HIV                                                -0.036219  0.006728
STDs:Hepatitis B                                        -0.019053 -0.011276
STDs:HPV                                                 0.054049 -0.015956
STDs: Number of diagnosis                               -0.027758  0.035041
Dx:Cancer                                                0.064284  0.116834
Dx:CIN                                                   0.010248  0.009019
Dx:HPV                                                   0.083980  0.061781
Dx                                                       0.010709  0.116183
Hinselmann                                               0.057177  0.034055
Schiller                                                 0.084960  0.087015
Citology                                                 0.057271  0.032660
Biopsy                                                   0.076637  0.046396

                                    …  STDs:HPV  STDs: Number of diagnosis  \
Age                                 …  0.045525                   0.006700
Number of sexual partners           …  0.013904                   0.050313
First sexual intercourse            …  0.034700                  -0.014101
Num of pregnancies                  … -0.025530                   0.046418
Smokes                              …  0.049727                   0.092415
Smokes (years)                      …  0.055122                   0.087610
Smokes (packs/year)                 … -0.008004                   0.030078
Hormonal Contraceptives             …  0.034623                  -0.046731
Hormonal Contraceptives (years)     …  0.054049                  -0.027758
IUD                                 … -0.015956                   0.035041
IUD (years)                         … -0.011811                   0.013104
STDs                                …  0.151725                   0.907739
STDs (number)                       …  0.077076                   0.898375
STDs:condylomatosis                 … -0.011333                   0.701545
STDs:vaginal condylomatosis         … -0.003335                   0.206469
STDs:vulvo-perineal condylomatosis  … -0.011197                   0.693098
STDs:syphilis                       … -0.007135                   0.414744
STDs:pelvic inflammatory disease    … -0.001665                   0.103052
STDs:genital herpes                 … -0.001665                   0.103052
STDs:molluscum contagiosum          … -0.001665                   0.103052
STDs:HIV                            … -0.007135                   0.549282
STDs:Hepatitis B                    … -0.001665                   0.103052
STDs:HPV                            …  1.000000                   0.065865
STDs: Number of diagnosis           …  0.065865                   1.000000
Dx:Cancer                           …  0.330177                  -0.015778
```

```
Dx:CIN                              … -0.004728                   0.011834
Dx:HPV                              …  0.330177                  -0.015778
Dx                                  …  0.141562                  -0.000645
Hinselmann                          … -0.009901                   0.079145
Schiller                            … -0.014643                   0.136406
Citology                            … -0.011197                   0.056747
Biopsy                              … -0.012508                   0.101398

                                    Dx:Cancer    Dx:CIN    Dx:HPV        Dx  \
Age                                  0.123406  0.023543  0.114101  0.077433
Number of sexual partners            0.022300  0.020522  0.027253  0.025772
First sexual intercourse             0.067100 -0.017514  0.043718  0.046541
Num of pregnancies                   0.041851  0.019837  0.053769  0.031295
Smokes                              -0.013080 -0.039661  0.010304 -0.067855
Smokes (years)                       0.058383 -0.029023  0.061080 -0.049654
Smokes (packs/year)                  0.107425 -0.019582  0.109316 -0.033502
Hormonal Contraceptives              0.018492  0.017978  0.035766  0.011599
Hormonal Contraceptives (years)      0.064284  0.010248  0.083980  0.010709
IUD                                  0.116834  0.009019  0.061781  0.116183
IUD (years)                          0.104382  0.010001  0.036566  0.103862
STDs                                 0.009259  0.010798  0.009259 -0.003374
STDs (number)                       -0.012499 -0.005737 -0.012499 -0.021749
STDs:condylomatosis                 -0.034324 -0.022747 -0.034324 -0.038917
STDs:vaginal condylomatosis         -0.010102 -0.006695 -0.010102 -0.011453
STDs:vulvo-perineal condylomatosis  -0.033911 -0.022473 -0.033911 -0.038448
STDs:syphilis                       -0.021609 -0.014320 -0.021609 -0.024500
STDs:pelvic inflammatory disease    -0.005042 -0.003341 -0.005042 -0.005717
STDs:genital herpes                 -0.005042 -0.003341 -0.005042 -0.005717
STDs:molluscum contagiosum          -0.005042 -0.003341 -0.005042 -0.005717
STDs:HIV                            -0.021609  0.070308 -0.021609  0.025861
STDs:Hepatitis B                    -0.005042 -0.003341 -0.005042 -0.005717
STDs:HPV                             0.330177 -0.004728  0.330177  0.141562
STDs: Number of diagnosis           -0.015778  0.011834 -0.015778 -0.000645
Dx:Cancer                            1.000000 -0.014320  0.886488  0.680550
Dx:CIN                              -0.014320  1.000000 -0.014320  0.584497
Dx:HPV                               0.886488 -0.014320  1.000000  0.630189
Dx                                   0.680550  0.584497  0.630189  1.000000
Hinselmann                           0.136806 -0.019873  0.136806  0.077000
Schiller                             0.162374  0.014644  0.162374  0.106942
Citology                             0.115228 -0.022473  0.115228  0.093885
Biopsy                               0.164877  0.126060  0.164877  0.166946

                                    Hinselmann  Schiller  Citology    Biopsy
Age                                  -0.016784  0.067803 -0.025413  0.041659
Number of sexual partners            -0.043440 -0.011495  0.023791 -0.002841
First sexual intercourse             -0.017350 -0.001775 -0.011714  0.006744
Num of pregnancies                    0.037163  0.066088 -0.021527  0.032965
```

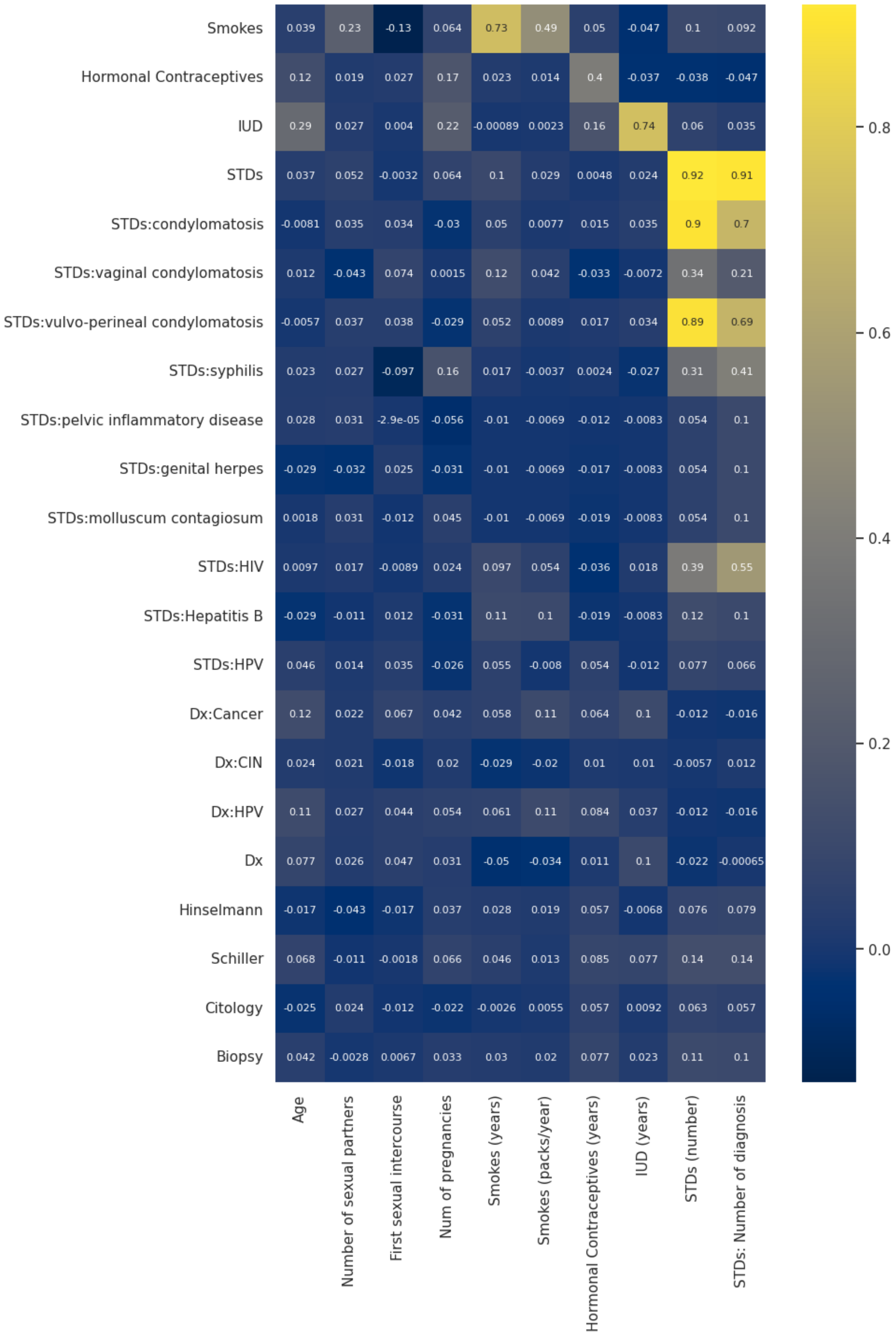
```
Smokes                               0.020027  0.035344 -0.001751  0.020386
Smokes (years)                       0.027587  0.045542 -0.002630  0.030026
Smokes (packs/year)                  0.018572  0.012742  0.005480  0.019554
Hormonal Contraceptives              0.031303 -0.009485 -0.039697 -0.001293
Hormonal Contraceptives (years)      0.057177  0.084960  0.057271  0.076637
IUD                                  0.034055  0.087015  0.032660  0.046396
IUD (years)                         -0.006759  0.076929  0.009205  0.023429
STDs                                 0.058795  0.123132  0.055613  0.118630
STDs (number)                        0.075509  0.135198  0.063411  0.107235
STDs:condylomatosis                  0.060753  0.121458  0.067276  0.093542
STDs:vaginal condylomatosis         -0.014019 -0.020733 -0.015853 -0.017710
STDs:vulvo-perineal condylomatosis   0.062511  0.124405  0.069249  0.095947
STDs:syphilis                        0.011711  0.014714 -0.033911 -0.037884
STDs:pelvic inflammatory disease    -0.006997 -0.010348 -0.007913 -0.008839
STDs:genital herpes                 -0.006997 -0.010348 -0.007913  0.133093
STDs:molluscum contagiosum          -0.006997 -0.010348 -0.007913 -0.008839
STDs:HIV                             0.095108  0.132842  0.077943  0.131083
STDs:Hepatitis B                    -0.006997 -0.010348 -0.007913 -0.008839
STDs:HPV                            -0.009901 -0.014643 -0.011197 -0.012508
STDs: Number of diagnosis            0.079145  0.136406  0.056747  0.101398
Dx:Cancer                            0.136806  0.162374  0.115228  0.164877
Dx:CIN                              -0.019873  0.014644 -0.022473  0.126060
Dx:HPV                               0.136806  0.162374  0.115228  0.164877
Dx                                   0.077000  0.106942  0.093885  0.166946
Hinselmann                           1.000000  0.654458  0.199476  0.543296
Schiller                             0.654458  1.000000  0.357211  0.731103
Citology                             0.199476  0.357211  1.000000  0.317946
Biopsy                               0.543296  0.731103  0.317946  1.000000

[32 rows x 32 columns]
```

[20]:

```python
x_corr = ccrf_df.corr().drop(num_cols, axis=0)
cat_corr = x_corr.drop(cat_cols, axis=1)

cat_corr

sns.set(rc = {'figure.figsize':(10, 15)})
sns.heatmap(cat_corr, annot=True, cmap='cividis',annot_kws={'size': 8},␣
  ↪square=True)
```

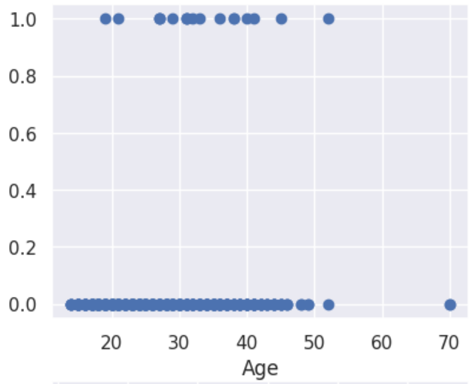
[20]:

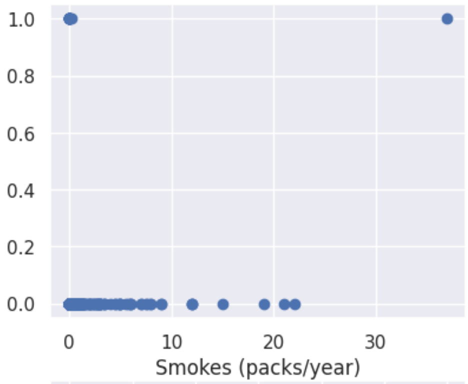
```
<Axes: >
```

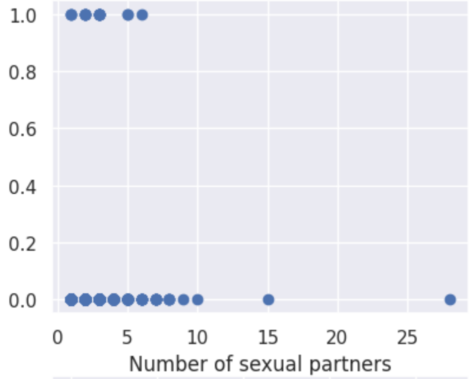

Smokes 0.039 0.23 -0.13 0.064 0.73 0.49 0.05 -0.047 0.1 0.092
Hormonal Contraceptives 0.12 0.019 0.027 0.17 0.023 0.014 0.4 -0.037 -0.038 -0.047
IUD 0.29 0.027 0.004 0.22 -0.00089 0.0023 0.16 0.74 0.06 0.035
STDs 0.037 0.052 -0.0032 0.064 0.1 0.029 0.0048 0.024 0.92 0.91
STDs:condylomatosis -0.0081 0.035 0.034 -0.03 0.05 0.0077 0.015 0.035 0.9 0.7
STDs:vaginal condylomatosis 0.012 -0.043 0.074 0.0015 0.12 0.042 -0.033 -0.0072 0.34 0.21
STDs:vulvo-perineal condylomatosis -0.0057 0.037 0.038 -0.029 0.052 0.0089 0.017 0.034 0.89 0.69
STDs:syphilis 0.023 0.027 -0.097 0.16 0.017 -0.0037 0.0024 -0.027 0.31 0.41
STDs:pelvic inflammatory disease 0.028 0.031 -2.9e-05 -0.056 -0.01 -0.0069 -0.012 -0.0083 0.054 0.1
STDs:genital herpes -0.029 -0.032 0.025 -0.031 -0.01 -0.0069 -0.017 -0.0083 0.054 0.1
STDs:molluscum contagiosum 0.0018 0.031 -0.012 0.045 -0.01 -0.0069 -0.019 -0.0083 0.054 0.1
STDs:HIV 0.0097 0.017 -0.0089 0.024 0.097 0.054 -0.036 0.018 0.39 0.55
STDs:Hepatitis B -0.029 -0.011 0.012 -0.031 0.11 0.1 -0.019 -0.0083 0.12 0.1
STDs:HPV 0.046 0.014 0.035 -0.026 0.055 -0.008 0.054 -0.012 0.077 0.066
Dx:Cancer 0.12 0.022 0.067 0.042 0.058 0.11 0.064 0.1 -0.012 -0.016
Dx:CIN 0.024 0.021 -0.018 0.02 -0.029 -0.02 0.01 0.01 -0.0057 0.012
Dx:HPV 0.11 0.027 0.044 0.054 0.061 0.11 0.084 0.037 -0.012 -0.016
Dx 0.077 0.026 0.047 0.031 -0.05 -0.034 0.011 0.1 -0.022 -0.00065
Hinselmann -0.017 -0.043 -0.017 0.037 0.028 0.019 0.057 -0.0068 0.076 0.079
Schiller 0.068 -0.011 -0.0018 0.066 0.046 0.013 0.085 0.077 0.14 0.14
Citology -0.025 0.024 -0.012 -0.022 -0.0026 0.0055 0.057 0.0092 0.063 0.057
Biopsy 0.042 -0.0028 0.0067 0.033 0.03 0.02 0.077 0.023 0.11 0.1
Age
Number of sexual partners
First sexual intercourse
Num of pregnancies
Smokes (years)
Smokes (packs/year)
Hormonal Contraceptives (years)
IUD (years)
STDs (number)
STDs: Number of diagnosis
0.8
0.6
0.4
0.2
0.0

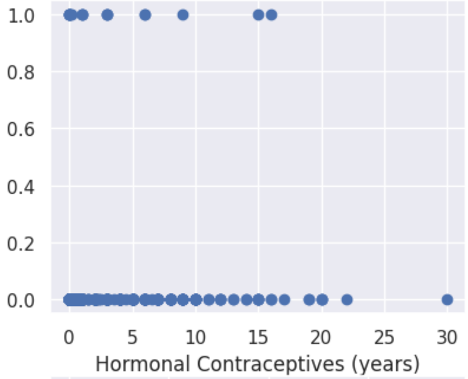
[21]:

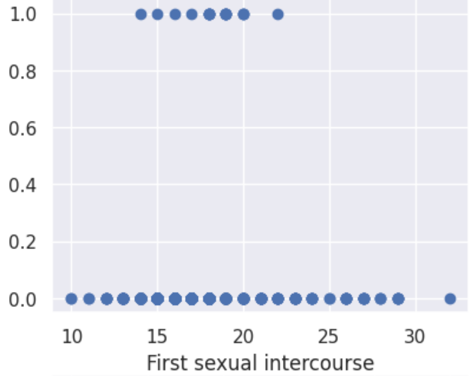
```
num1 = num_cols[:5]
num2 = num_cols[5:]

fig, ax = plt.subplots(nrows= 5, ncols=2, figsize=(10, 20))

ind = 0

for row in ax:
  row[0].scatter(ccrf_df[num1[ind]], ccrf_df['Dx:Cancer'])
  row[0].set_xlabel(num1[ind])
  row[1].scatter(ccrf_df[num2[ind]], ccrf_df['Dx:Cancer'])
  row[1].set_xlabel(num2[ind])
  ind += 1
```

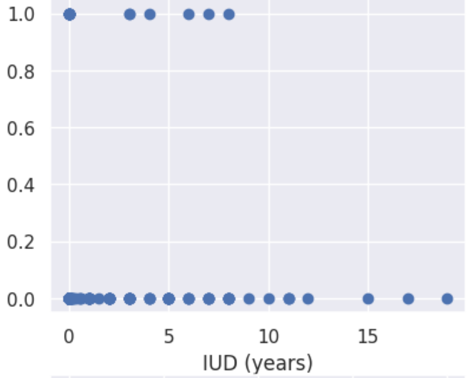

1.0
0.8
0.6
0.4
0.2
0.0
20
30
40
50
60
70
Age

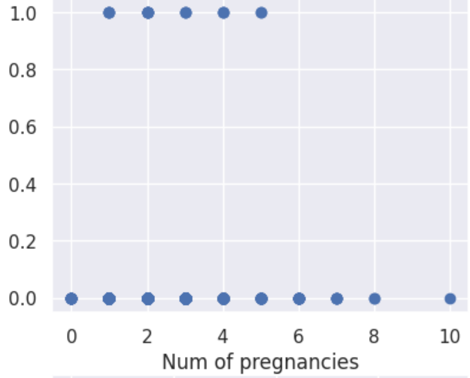

1.0
0.8
0.6
0.4
0.2
0.0
0
10
20
30
Smokes (packs/year)

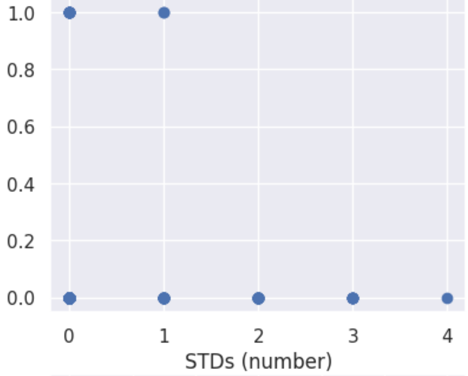

1.0
0.8
0.6
0.4
0.2
0.0
0
5
10
15
20
25
Number of sexual partners

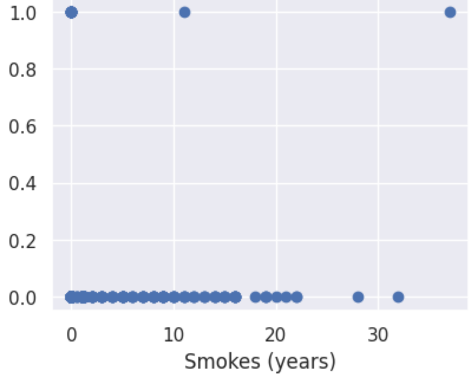

1.0
0.8
0.6
0.4
0.2
0.0
0
5
10
15
20
25
30
Hormonal Contraceptives (years)

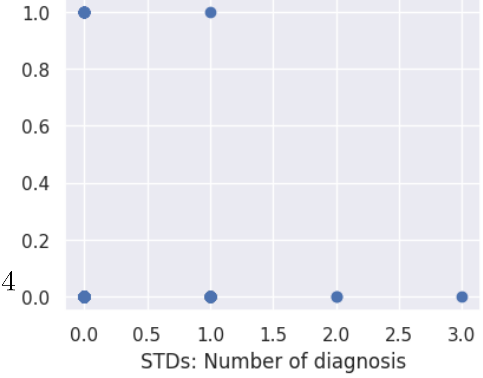

1.0
0.8
0.6
0.4
0.2
0.0
10
15
20
25
30
First sexual intercourse


1.0
0.8
0.6
0.4
0.2
0.0
0
5
10
15
IUD (years)


1.0
0.8
0.6
0.4
0.2
0.0
0
2
4
6
8
10
Num of pregnancies


1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
STDs (number)


1.0
0.8
0.6
0.4
0.2
0.0
0
10
20
30
Smokes (years)


1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
STDs: Number of diagnosis

1.6.4 Logistic Regression

Declare feature vector and target variable

```
[22]: X = ccrf_df.drop(cat_cols, axis=1)
      y = ccrf_df['Schiller']
```

Split data into separate training and test set

```
[23]: from sklearn.model_selection import train_test_split

      X_train, X_test, y_train, y_test = train_test_split(X, y, test_size = 0.3,␣
       ↪random_state=0)
```

```
[24]: X_train.shape, X_test.shape
```

```
[24]: ((595, 10), (256, 10))
```

```
[25]: from sklearn.preprocessing import StandardScaler

      scaler = StandardScaler()

      X_train_scaled = scaler.fit_transform(X_train)

      X_test_scaled = scaler.transform(X_test)

      X_train_scaled
```

```
[25]: array([[-8.19614616e-01, -1.04033386e+00, -7.14782754e-01, …,
              -2.46062766e-01, -2.85220215e-01, -2.82879693e-01],
             [-4.44579474e-01, -3.53320935e-01,  3.64648055e-01, …,
              -2.46062766e-01, -2.85220215e-01, -2.82879693e-01],
             [ 3.18076023e+00, -3.53320935e-01,  7.24458325e-01, …,
               5.26966023e+00, -2.85220215e-01, -2.82879693e-01],
             …,
             [-6.95443317e-02, -3.53320935e-01,  3.64648055e-01, …,
              -2.46062766e-01, -2.85220215e-01, -2.82879693e-01],
             [ 1.43059624e+00, -1.04033386e+00,  2.52350967e+00, …,
              -2.46062766e-01, -2.85220215e-01, -2.82879693e-01],
             [-6.95443317e-02, -3.53320935e-01,  4.83778514e-03, …,
              -2.46062766e-01,  3.44458259e+00,  3.01738339e+00]])
```

```
[26]: X_test_scaled
```

```
[26]: array([[ 2.68071338,  1.02070492, -0.35497248, …,  0.2553666 ,
              -0.28522021, -0.28287969],
             [ 0.30549081, -0.35332093,  0.36464805, …, -0.24606277,
              -0.28522021, -0.28287969],
             [-1.31966147,  0.33369199, -1.07459302, …, -0.24606277,
              -0.28522021, -0.28287969],
             …,
             [-0.31956776, -0.35332093,  0.36464805, …, -0.24606277,
              -0.28522021, -0.28287969],
             [ 1.18057281,  0.33369199,  1.08426859, …, -0.24606277,
               1.57968119,  3.01738339],
             [ 0.55551424,  0.33369199,  0.36464805, …, -0.24606277,
              -0.28522021, -0.28287969]])
```

```
[27]: from sklearn.linear_model import LogisticRegression

      log_reg = LogisticRegression(random_state = 0).fit(X_train_scaled, y_train)
```

```
[28]: log_reg.score(X_train_scaled, y_train)
```

```
[28]: 0.9176470588235294
```

```
[29]: log_reg.score(X_test_scaled, y_test)
```

```
[29]: 0.9140625
```

```
[30]: log_reg1 = LogisticRegression(random_state = 0,
                                    C=0.01,
                                    fit_intercept= True,
                                    ).fit(X_train_scaled, y_train)
```

```
[31]: log_reg1.score(X_train_scaled,y_train)
```

```
[31]: 0.9176470588235294
```

```
[32]: log_reg1.score(X_test_scaled, y_test)
```

```
[32]: 0.9140625
```

1.6.5 Conclusion

From the activity, I was able to learn about Logistic Regression and see how it is very similar to Linear Regression. With Logistic Regression, the outcome that we are trying to predict is in boolean form, only representing values as 0 or 1, True or False. With this, we are able to use Logistic Regression to predict classification for our data being used to predict with the model. We are able to deal with categorical data instead of just continuous numerical data. It is important to learn Logistic Regression in order to predict and classify a given set of data