Salifort Motors project

May 6, 2024

1 Improving Employee Retention of Salifort Motors

1.1 About Salifort Motors

Salifort motors is a French based fictional company. It is alternative energy vehicle manufacturer. r. Its global workforce of over 100,000 employees research, design, construct, validate, and distribute electric, solar, algae, and hydrogen-based vehicles.

1.2 Business Case

Currently, there is high turn over rate among Salifort employees. The company's senior leadership is quite concerned about this issue as a high turn over rate is costly in the financial sense. The company makes a big investment in recruiting, training, and upskilling its employees.

In order to tackle this challenge, the key factors driving employee turnover should be analyzed. It is also recommended to determine whether an employee will leave the company based on their job title, department, number of projects, average monthly hours, and any other relevant data points. This will help the company increase retention and job satisfaction for current employees, and save money and time training new employees

To start off, the HR team has conducted a survey of the sample of employees to acquire data about them. Now there is a need to analyze this data and also proivde data-driven suggestions in order to counter this issue

1.3 Business Task

To analyze the data of Salifort employees and build a model that predicts whether or not an employee will leave the company,

1.4 Data Source

The employees survey data is stored in a single CSV file. It can be accessed through dataset"

The dataset possesses the qualities of 'ROCCC' as: Dataset is provided by a trusted organization (Google) - 'Reliable' and 'Original'

For the purpose of this case study, the data volume is sufficient to perform the analysis - 'Comprehensive'

This is a ficitonal dataset created for case study objectives which makes it current and accurate - 'Current'

The dataset is licensed under CCO: Public Domain - 'Cited'. The license can be accessed through "https://creativecommons.org/publicdomain/zero/1.0/"

1.5 Pace: Plan

In this stage, consider the following:

1.5.1 HR dataset

In this dataset, there are 14,999 rows, 10 columns, and these variables:

Variable	Description
satisfaction_level	Employee-reported job satisfaction level [0–1]
last_evaluation	Score of employee's last performance review [0–1]
number_project	Number of projects employee contributes to
average_monthly_hours	Average number of hours employee worked per month
time_spend_company	How long the employee has been with the company (years)
Work_accident	Whether or not the employee experienced an accident while at work
left	Whether or not the employee left the company
promotion_last_5years	Whether or not the employee was promoted in the last 5 years
Department	The employee's department
salary	The employee's salary (U.S. dollars)

1.5.2 Reflect on these questions as you complete the plan stage.

- Who are your stakeholders for this project?
- What are you trying to solve or accomplish?
- What are your initial observations when you explore the data?
- What resources do you find yourself using as you complete this stage? (Make sure to include the links.)
- Do you have any ethical considerations in this stage?

Stakeholders

Salifort HR Department, Salifort's senior leadership team

Problem

High turnover rate among Salifort employees. Aim - to discover the reasons, come up with ideas for how to increase employee turnover rate, build effective model to predict employee departure.

Initial observations and What resources do you find yourself using as you complete this stage?

links - https://www.togetherplatform.com/blog/top-reasons-for-employee-turnover - https://www.netsuite.com/portal/resource/articles/human-resources/employee-turnover-causes.shtml

These are some of the resources I investigated to find out about reasons for employee turnover.

Some potential reasons for employee turnover that alligns with the data provided are : - satisfaction level - Beeing overworked (corresponds to column with average monthly hours) - No opportunity for growth or development(column with promotion status) - Poor compensation - salary

Ethical considerations - Ownership (Kaggle): Owner of data Faisal Qureshi. We don't now how the data collection process was organized, bus acording to license, hopefully, that there were consent, privacy and transaction transparancy

- Openness: According to Kaggle :License CC0: Public Domain. That means that anyone can copy, modify, distribute and perform the work, even for commercial purposes, all without asking permission

- Data doesn't contain PII (personally identifieble information)

1.6 Step 1. Imports

- Import packages
- Load dataset

1.6.1 Import packages

```python
# Import packages

# For data manipulation
import numpy as np
import pandas as pd

# For data visualization
import matplotlib.pyplot as plt
import seaborn as sns

# For displaying all of the columns in dataframes
pd.set_option('display.max_columns', None)

# For data modeling
from xgboost import XGBClassifier
from xgboost import XGBRegressor
from xgboost import plot_importance

from sklearn.linear_model import LogisticRegression
from sklearn.tree import DecisionTreeClassifier
from sklearn.ensemble import RandomForestClassifier

# For metrics and helpful functions
```

```python
from sklearn.model_selection import GridSearchCV, train_test_split
from sklearn.metrics import accuracy_score, precision_score, recall_score,\
f1_score, confusion_matrix, ConfusionMatrixDisplay, classification_report
from sklearn.metrics import roc_auc_score, roc_curve
from sklearn.tree import plot_tree

# For saving models
import pickle
```

1.6.2 Load dataset

```python
[5]: # Load dataset into a dataframe
df0 = pd.read_csv("HR_comma_sep.csv")

# Display first few rows of the dataframe
df0.head()
```

```
[5]:    satisfaction_level  last_evaluation  number_project  average_montly_hours  \
    0                0.38             0.53               2                   157
    1                0.80             0.86               5                   262
    2                0.11             0.88               7                   272
    3                0.72             0.87               5                   223
    4                0.37             0.52               2                   159

       time_spend_company  Work_accident  left  promotion_last_5years Department  \
    0                   3              0     1                      0      sales
    1                   6              0     1                      0      sales
    2                   4              0     1                      0      sales
    3                   5              0     1                      0      sales
    4                   3              0     1                      0      sales

       salary
    0     low
    1  medium
    2  medium
    3     low
    4     low
```

1.7 Step 2. Data Exploration (Initial EDA and data cleaning)

- Understand your variables
- Clean your dataset (missing data, redundant data, outliers)

1.7.1 Gather basic information about the data

```
[6]: # Gather basic information about the data
     df0.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 14999 entries, 0 to 14998
Data columns (total 10 columns):
 #   Column                 Non-Null Count  Dtype
---  ------                 --------------  -----
 0   satisfaction_level     14999 non-null  float64
 1   last_evaluation        14999 non-null  float64
 2   number_project         14999 non-null  int64
 3   average_montly_hours   14999 non-null  int64
 4   time_spend_company     14999 non-null  int64
 5   Work_accident          14999 non-null  int64
 6   left                   14999 non-null  int64
 7   promotion_last_5years  14999 non-null  int64
 8   Department             14999 non-null  object
 9   salary                 14999 non-null  object
dtypes: float64(2), int64(6), object(2)
memory usage: 1.1+ MB
```

1.7.2 Gather descriptive statistics about the data

```
[7]: # Gather descriptive statistics about the data
     df0.describe()
```

[7]:

	satisfaction_level	last_evaluation	number_project \
count	14999.000000	14999.000000	14999.000000
mean	0.612834	0.716102	3.803054
std	0.248631	0.171169	1.232592
min	0.090000	0.360000	2.000000
25%	0.440000	0.560000	3.000000
50%	0.640000	0.720000	4.000000
75%	0.820000	0.870000	5.000000
max	1.000000	1.000000	7.000000

	average_montly_hours	time_spend_company	Work_accident	left \
count	14999.000000	14999.000000	14999.000000	14999.000000
mean	201.050337	3.498233	0.144610	0.238083
std	49.943099	1.460136	0.351719	0.425924
min	96.000000	2.000000	0.000000	0.000000
25%	156.000000	3.000000	0.000000	0.000000
50%	200.000000	3.000000	0.000000	0.000000
75%	245.000000	4.000000	0.000000	0.000000
max	310.000000	10.000000	1.000000	1.000000

```
        promotion_last_5years
count           14999.000000
mean                0.021268
std                 0.144281
min                 0.000000
25%                 0.000000
50%                 0.000000
75%                 0.000000
max                 1.000000
```

1.7.3 Rename columns

As a data cleaning step, rename the columns as needed. Standardize the column names so that they are all in `snake_case`, correct any column names that are misspelled, and make column names more concise as needed.

```
[8]: # Display all column names
     df0.columns
```

```
[8]: Index(['satisfaction_level', 'last_evaluation', 'number_project',
            'average_montly_hours', 'time_spend_company', 'Work_accident', 'left',
            'promotion_last_5years', 'Department', 'salary'],
           dtype='object')
```

```
[9]: # Rename columns as needed
     df0 = df0.rename(columns={'Work_accident': 'work_accident',
                               'average_montly_hours': 'average_monthly_hours',
                               'time_spend_company': 'tenure',
                               'Department': 'department'})

     # Display all column names
     df0.columns
```

```
[9]: Index(['satisfaction_level', 'last_evaluation', 'number_project',
            'average_monthly_hours', 'tenure', 'work_accident', 'left',
            'promotion_last_5years', 'department', 'salary'],
           dtype='object')
```

1.7.4 Check missing values

Check for any missing values in the data.

```
[10]: # Check for missing values
      df0.isna().sum()
```

```
[10]: satisfaction_level     0
      last_evaluation        0
      number_project         0
```

```
average_monthly_hours     0
tenure                    0
work_accident             0
left                      0
promotion_last_5years     0
department                0
salary                    0
dtype: int64
```

There are no missing values in the data.

1.7.5 Check duplicates

Check for any duplicate entries in the data.

```
[11]: # Check for duplicates
      ### YOUR CODE HERE ###
      df0.duplicated().sum()
```

[11]: 3008

3,008 rows contain duplicates. That is 20% of the data.

```
[12]: # Inspect some rows containing duplicates as needed

      df0[df0.duplicated()].head()
```

```
[12]:       satisfaction_level  last_evaluation  number_project  \
      396                 0.46             0.57               2
      866                 0.41             0.46               2
      1317                0.37             0.51               2
      1368                0.41             0.52               2
      1461                0.42             0.53               2

            average_monthly_hours  tenure  work_accident  left  \
      396                     139       3              0     1
      866                     128       3              0     1
      1317                    127       3              0     1
      1368                    132       3              0     1
      1461                    142       3              0     1

            promotion_last_5years  department  salary
      396                       0       sales     low
      866                       0  accounting     low
      1317                      0       sales  medium
      1368                      0       RandD     low
      1461                      0       sales     low
```

```
[13]: # Drop duplicates and save resulting dataframe in a new variable

      df1 = df0.drop_duplicates(keep='first')

      # Display first few rows of new dataframe
      df1.head()
```

```
[13]:    satisfaction_level  last_evaluation  number_project  average_monthly_hours  \
      0                0.38             0.53               2                    157
      1                0.80             0.86               5                    262
      2                0.11             0.88               7                    272
      3                0.72             0.87               5                    223
      4                0.37             0.52               2                    159

         tenure  work_accident  left  promotion_last_5years department  salary
      0       3              0     1                      0      sales     low
      1       6              0     1                      0      sales  medium
      2       4              0     1                      0      sales  medium
      3       5              0     1                      0      sales     low
      4       3              0     1                      0      sales     low
```
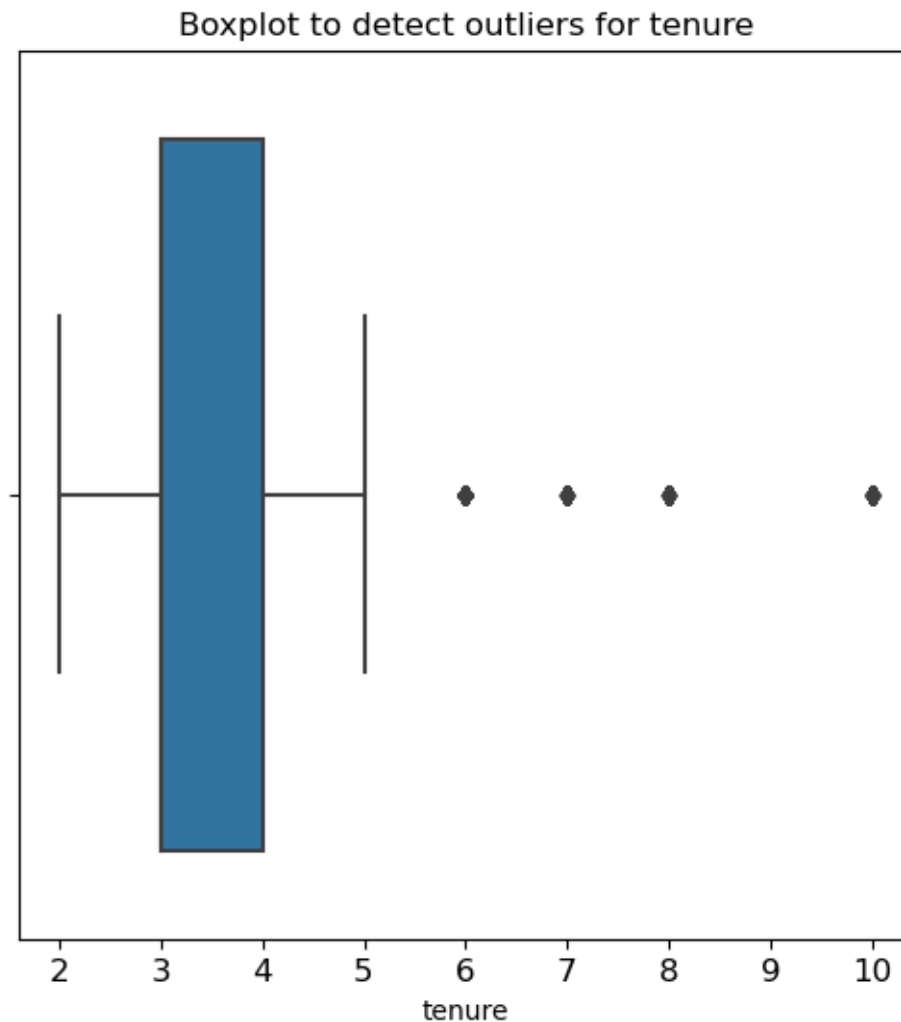
1.7.6 Check outliers

Check for outliers in the data.

```
[14]: # Create a boxplot to visualize distribution of `tenure` and detect any outliers
      plt.figure(figsize=(6,6))
      plt.title('Boxplot to detect outliers for tenure', fontsize=12)
      plt.xticks(fontsize=12)
      plt.yticks(fontsize=12)
      sns.boxplot(x=df1['tenure'])
      plt.show()
```

Boxplot to detect outliers for tenure

The boxplot above shows that there are outliers in the `tenure` variable.

It would be helpful to investigate how many rows in the data contain outliers in the `tenure` column.

```
[15]:  # Determine the number of rows containing outliers

       # Compute the 25th percentile value in `tenure`
       percentile25 = df1['tenure'].quantile(0.25)

       # Compute the 75th percentile value in `tenure`
       percentile75 = df1['tenure'].quantile(0.75)

       # Compute the interquartile range in `tenure`
       iqr = percentile75 - percentile25

       # Define the upper limit and lower limit for non-outlier values in `tenure`
```

```
upper_limit = percentile75 + 1.5 * iqr
lower_limit = percentile25 - 1.5 * iqr
print("Lower limit:", lower_limit)
print("Upper limit:", upper_limit)

# Identify subset of data containing outliers in `tenure`
outliers = df1[(df1['tenure'] > upper_limit) | (df1['tenure'] < lower_limit)]

# Count how many rows in the data contain outliers in `tenure`
print("Number of rows in the data containing outliers in `tenure`:",␣
 ↪len(outliers))
```

```
Lower limit: 1.5
Upper limit: 5.5
Number of rows in the data containing outliers in `tenure`: 824
```

Certain types of models are more sensitive to outliers than others. When you get to the stage of building your model, consider whether to remove these outliers based on the type of model you decide to use.

2 pAce: Analyze Stage

- Perform EDA (analyze relationships between variables)

Reflect on these questions as you complete the analyze stage.

- What did you observe about the relationships between variables?
- What do you observe about the distributions in the data?
- What transformations did you make with your data? Why did you chose to make those decisions?
- What are some purposes of EDA before constructing a predictive model?
- What resources do you find yourself using as you complete this stage? (Make sure to include the links.)
- Do you have any ethical considerations in this stage?

2.1 Step 2. Data Exploration (Continue EDA)

Begin by understanding how many employees left and what percentage of all employees this figure represents.

[16]:
```
# Get numbers of people who left vs. stayed
print(df1['left'].value_counts())
print()

# Get percentages of people who left vs. stayed
print(df1['left'].value_counts(normalize=True))
```

```
0    10000
1     1991
Name: left, dtype: int64
```

```
0    0.833959
1    0.166041
Name: left, dtype: float64
```

We have majority class with 83.4% of employees who stayed in company, and minority class 16.6% with employees who left

Usually, major issues arise when majoruty class makes up 90% and more, so we won't fix imbalance, but do not forget to stratify all our test splits

2.1.1 Data visualizations

Now, examine variables that you're interested in, and create plots to visualize relationships between variables in the data.

  •

  •

```python
[17]: # Set figure and axes
      fig, ax = plt.subplots(1, 2, figsize = (22,8))

      # Create boxplot showing `average_monthly_hours` distributions for
       ↪`number_project`, comparing employees who stayed versus those who left
      sns.boxplot(data=df1, x='average_monthly_hours', y='number_project',
       ↪hue='left', orient="h", ax=ax[0])
      ax[0].invert_yaxis()
      ax[0].set_title('Monthly hours by number of projects', fontsize='14')

      # Create histogram showing distribution of `number_project`, comparing
       ↪employees who stayed versus those who left
      tenure_stay = df1[df1['left']==0]['number_project']
      tenure_left = df1[df1['left']==1]['number_project']
      sns.histplot(data=df1, x='number_project', hue='left', multiple='dodge',
       ↪shrink=2, ax=ax[1])
      ax[1].set_title('Number of projects histogram', fontsize='14')

      # Display the plots
      plt.show()
```
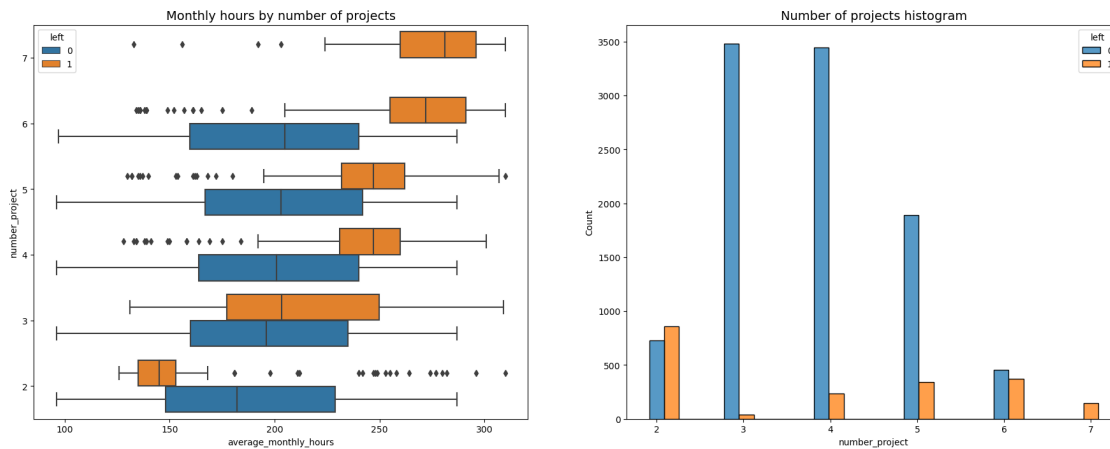
It might be natural that people who work on more projects would also work longer hours. This appears to be the case here, with the mean hours of each group (stayed and left) increasing with number of projects worked. However, a few things stand out from this plot.

1. There are two groups of employees who left the company: (A) those who worked considerably less than their peers with the same number of projects, and (B) those who worked much more. Of those in group A, it's possible that they were fired. It's also possible that this group includes employees who had already given their notice and were assigned fewer hours because they were already on their way out the door. For those in group B, it's reasonable to infer that 'they probably quit'. The folks in group B likely contributed a lot to the projects they worked in; they might have been the largest contributors to their projects.

2. Everyone with seven projects left the company, and the interquartile ranges of this group and those who left with six projects was ~255–295 hours/month—much more than any other group.

3. The optimal number of projects for employees to work on seems to be 3–4. The ratio of left/stayed is very small for these cohorts.

4. If you assume a work week of 40 hours and two weeks of vacation per year, then the average number of working hours per month of employees working Monday–Friday = `50 weeks * 40 hours per week / 12 months = 166.67 hours per month`. This means that, aside from the employees who worked on two projects, every group—even those who didn't leave the company—worked considerably more hours than this. It seems that employees here are overworked.

As the next step, confirm that all employees with seven projects left.

```
[18]: # Get value counts of stayed/left for employees with 7 projects
      df1[df1['number_project']==7]['left'].value_counts()
```

```
[18]: 1    145
      Name: left, dtype: int64
```

This confirms that all employees with 7 projects did leave.

Next, you could examine the average monthly hours versus the satisfaction levels.

```
[27]: # Create scatterplot of `average_monthly_hours` versus `satisfaction_level`,␣
      ↪comparing employees who stayed versus those who left
      plt.figure(figsize=(16, 9))
      sns.scatterplot(data=df1, x='average_monthly_hours', y='satisfaction_level',␣
      ↪hue='left', alpha=0.4)
      plt.axvline(x=166.67, color='#ff6361', label='166.67 hrs./mo.', ls='--')
      plt.legend(labels=['166.67 hrs./mo.', 'stayed', 'left'])
      plt.title('Monthly hours by last evaluation score', fontsize='14');
```
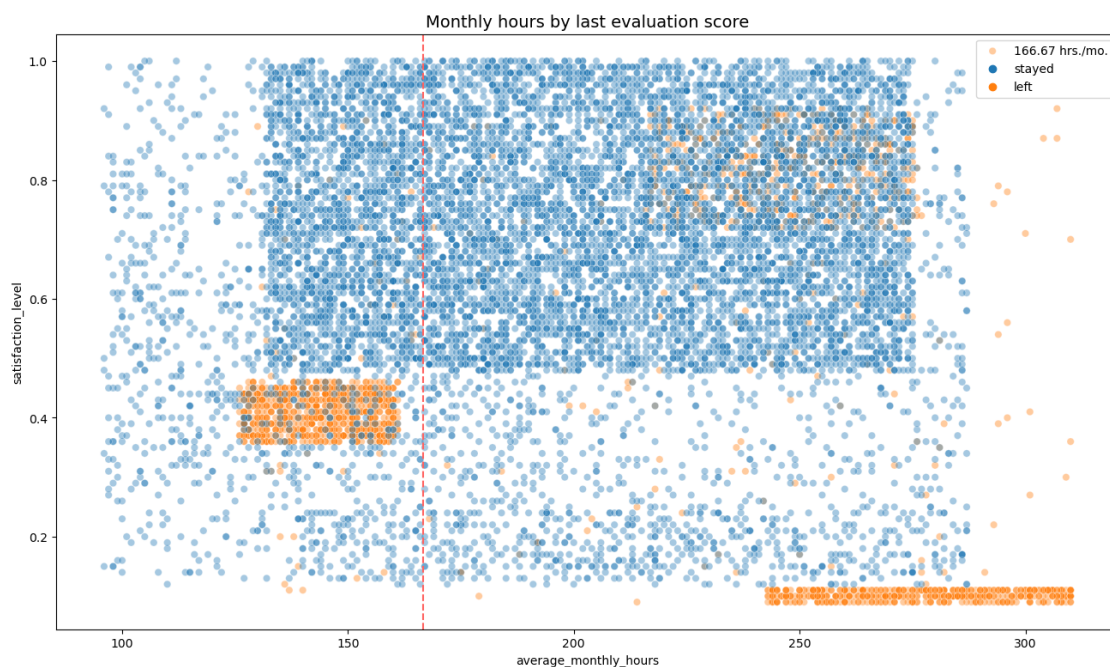

The scatterplot above shows that there was a sizeable group of employees who worked ~240–315 hours per month. 315 hours per month is over 75 hours per week for a whole year. It's likely this is related to their satisfaction levels being close to zero.

The plot also shows another group of people who left, those who had more normal working hours. Even so, their satisfaction was only around 0.4. It's difficult to speculate about why they might have left. It's possible they felt pressured to work more, considering so many of their peers worked more. And that pressure could have lowered their satisfaction levels.

Finally, there is a group who worked ~210–280 hours per month, and they had satisfaction levels ranging ~0.7–0.9.

Note the strange shape of the distributions here. This is indicative of data manipulation or synthetic data.

For the next visualization, it might be interesting to visualize satisfaction levels by tenure.

```
[28]: # Set figure and axes
fig, ax = plt.subplots(1, 2, figsize = (22,8))

# Create boxplot showing distributions of `satisfaction_level` by tenure,␣
↪comparing employees who stayed versus those who left
sns.boxplot(data=df1, x='satisfaction_level', y='tenure', hue='left',␣
↪orient="h", ax=ax[0])
ax[0].invert_yaxis()
ax[0].set_title('Satisfaction by tenure', fontsize='14')

# Create histogram showing distribution of `tenure`, comparing employees who␣
↪stayed versus those who left
tenure_stay = df1[df1['left']==0]['tenure']
tenure_left = df1[df1['left']==1]['tenure']
sns.histplot(data=df1, x='tenure', hue='left', multiple='dodge', shrink=5,␣
↪ax=ax[1])
ax[1].set_title('Tenure histogram', fontsize='14')

plt.show();
```
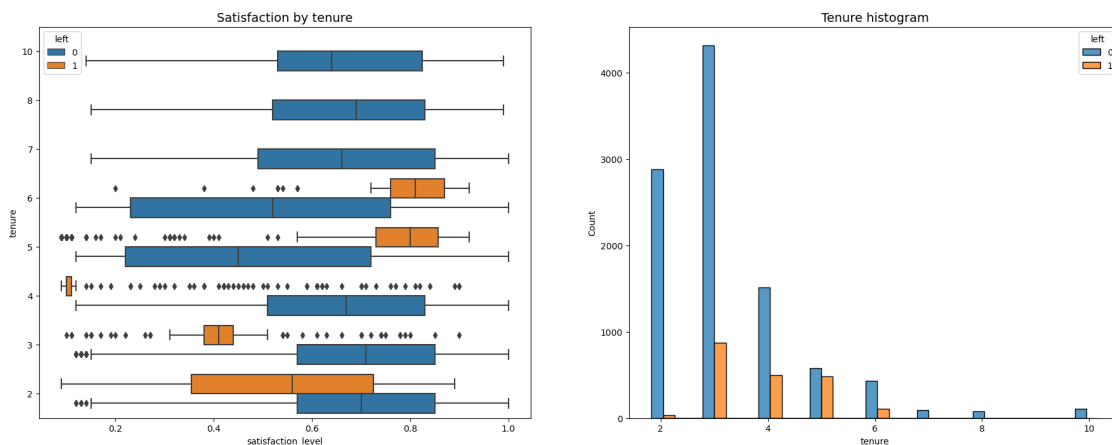

There are many observations you could make from this plot. - Employees who left fall into two general categories: dissatisfied employees with shorter tenures and very satisfied employees with medium-length tenures. - Four-year employees who left seem to have an unusually low satisfaction level. It's worth investigating changes to company policy that might have affected people specifically at the four-year mark, if possible. - The longest-tenured employees didn't leave. Their satisfaction levels aligned with those of newer employees who stayed. - The histogram shows that there are relatively few longer-tenured employees. It's possible that they're the higher-ranking, higher-paid employees.

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As the next step in analyzing the data, you could calculate the mean and median satisfaction scores of employees who left and those who didn't.

```
[29]: # Calculate mean and median satisfaction scores of employees who left and those␣
      ↪who stayed
      df1.groupby(['left'])['satisfaction_level'].agg([np.mean,np.median])
```

```
[29]:            mean   median
      left
      0      0.667365    0.69
      1      0.440271    0.41
```

As expected, the mean and median satisfaction scores of employees who left are lower than those of employees who stayed. Interestingly, among employees who stayed, the mean satisfaction score appears to be slightly below the median score. This indicates that satisfaction levels among those who stayed might be skewed to the left.

Next, you could examine salary levels for different tenures.

```
[30]: # Set figure and axes
      fig, ax = plt.subplots(1, 2, figsize = (22,8))

      # Define short-tenured employees
      tenure_short = df1[df1['tenure'] < 7]

      # Define long-tenured employees
      tenure_long = df1[df1['tenure'] > 6]

      # Plot short-tenured histogram
      sns.histplot(data=tenure_short, x='tenure', hue='salary', discrete=1,
                   hue_order=['low', 'medium', 'high'], multiple='dodge', shrink=.5,␣
       ↪ax=ax[0])
      ax[0].set_title('Salary histogram by tenure: short-tenured people',␣
       ↪fontsize='14')

      # Plot long-tenured histogram
      sns.histplot(data=tenure_long, x='tenure', hue='salary', discrete=1,
                   hue_order=['low', 'medium', 'high'], multiple='dodge', shrink=.4,␣
       ↪ax=ax[1])
      ax[1].set_title('Salary histogram by tenure: long-tenured people',␣
       ↪fontsize='14');
```
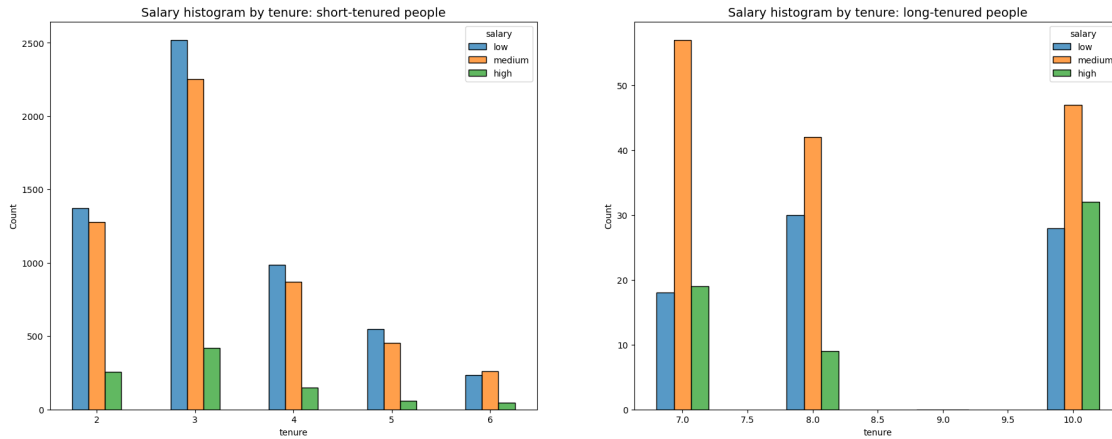
The plots above show that long-tenured employees were not disproportionately comprised of higher-paid employees.

Next, you could explore whether there's a correlation between working long hours and receiving high evaluation scores. You could create a scatterplot of `average_monthly_hours` versus `last_evaluation`.

```
[32]: # Create scatterplot of `average_monthly_hours` versus `last_evaluation`
plt.figure(figsize=(16, 9))
sns.scatterplot(data=df1, x='average_monthly_hours', y='last_evaluation',␣
 ↪hue='left', alpha=0.4)
plt.axvline(x=166.67, color='#ff6361', label='166.67 hrs./mo.', ls='--')
plt.legend(labels=['166.67 hrs./mo.', 'stayed', 'left'])
plt.title('Monthly hours by last evaluation score', fontsize='14');
```

Monthly hours by last evaluation score
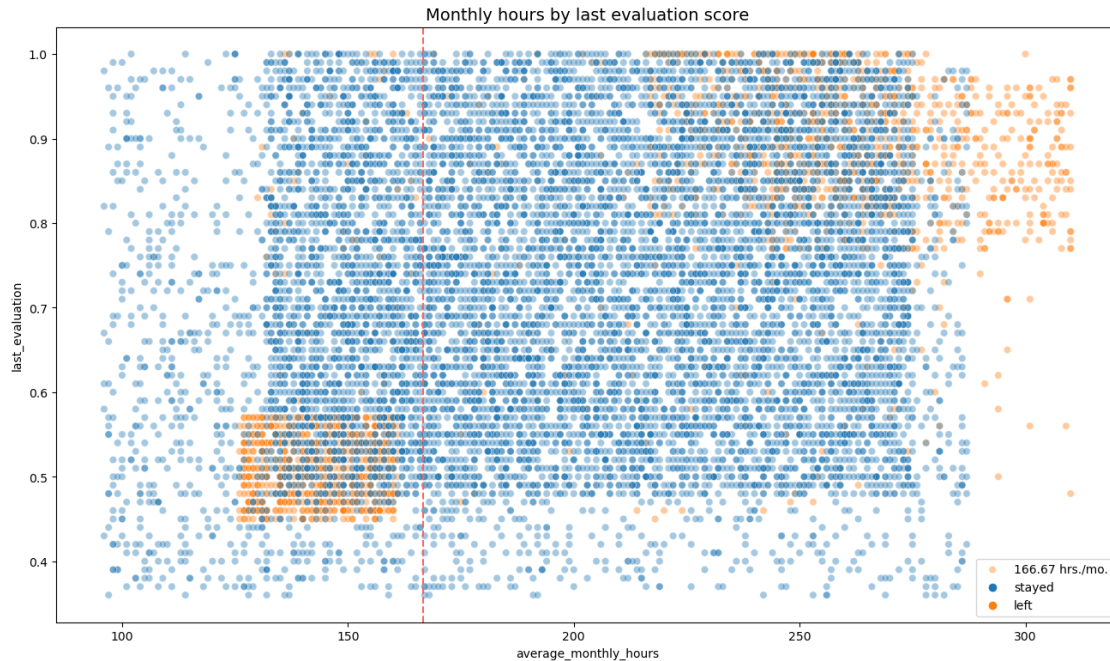
The following observations can be made from the scatterplot above: - The scatterplot indicates two groups of employees who left: overworked employees who performed very well and employees who worked slightly under the nominal monthly average of 166.67 hours with lower evaluation scores. - There seems to be a correlation between hours worked and evaluation score. - There isn't a high percentage of employees in the upper left quadrant of this plot; but working long hours doesn't guarantee a good evaluation score. - Most of the employees in this company work well over 167 hours per month.

Next, you could examine whether employees who worked very long hours were promoted in the last five years.

```
[34]:  # Create plot to examine relationship between `average_monthly_hours` and
       ↪`promotion_last_5years`
       plt.figure(figsize=(16, 3))
       sns.scatterplot(data=df1, x='average_monthly_hours', y='promotion_last_5years',
       ↪hue='left', alpha=0.4)
       plt.axvline(x=166.67, color='#ff6361', ls='--')
       plt.legend(labels=['166.67 hrs./mo.', 'stayed', 'left'])
       plt.title('Monthly hours by promotion last 5 years', fontsize='14');
```

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Monthly hours by promotion last 5 years
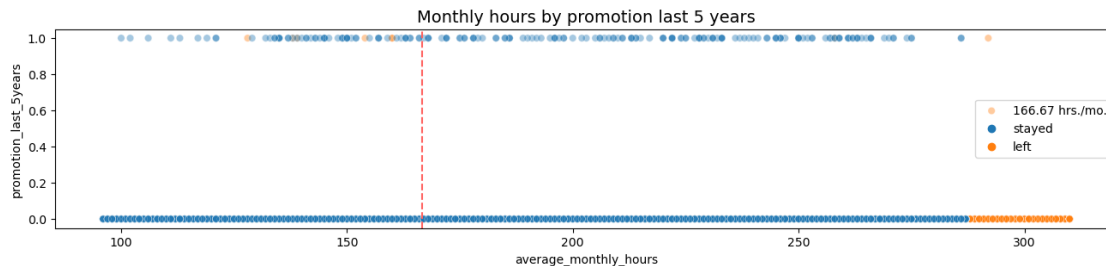
The plot above shows the following: - very few employees who were promoted in the last five years left - very few employees who worked the most hours were promoted - all of the employees who left were working the longest hours

Next, you could inspect how the employees who left are distributed across departments.

```
[35]: # Display counts for each department
      df1["department"].value_counts()
```

```
[35]: sales            3239
      technical        2244
      support          1821
      IT                976
      RandD             694
      product_mng       686
      marketing         673
      accounting        621
      hr                601
      management        436
      Name: department, dtype: int64
```

```
[37]: # Create stacked histogram to compare department distribution of employees who␣
      ↪left to that of employees who didn't
      plt.figure(figsize=(11,8))
      sns.histplot(data=df1, x='department', hue='left', discrete=1,
                   hue_order=[0, 1], multiple='dodge', shrink=.5)
      plt.xticks(rotation=45)
      plt.title('Counts of stayed/left by department', fontsize=14);
```

Counts of stayed/left by department
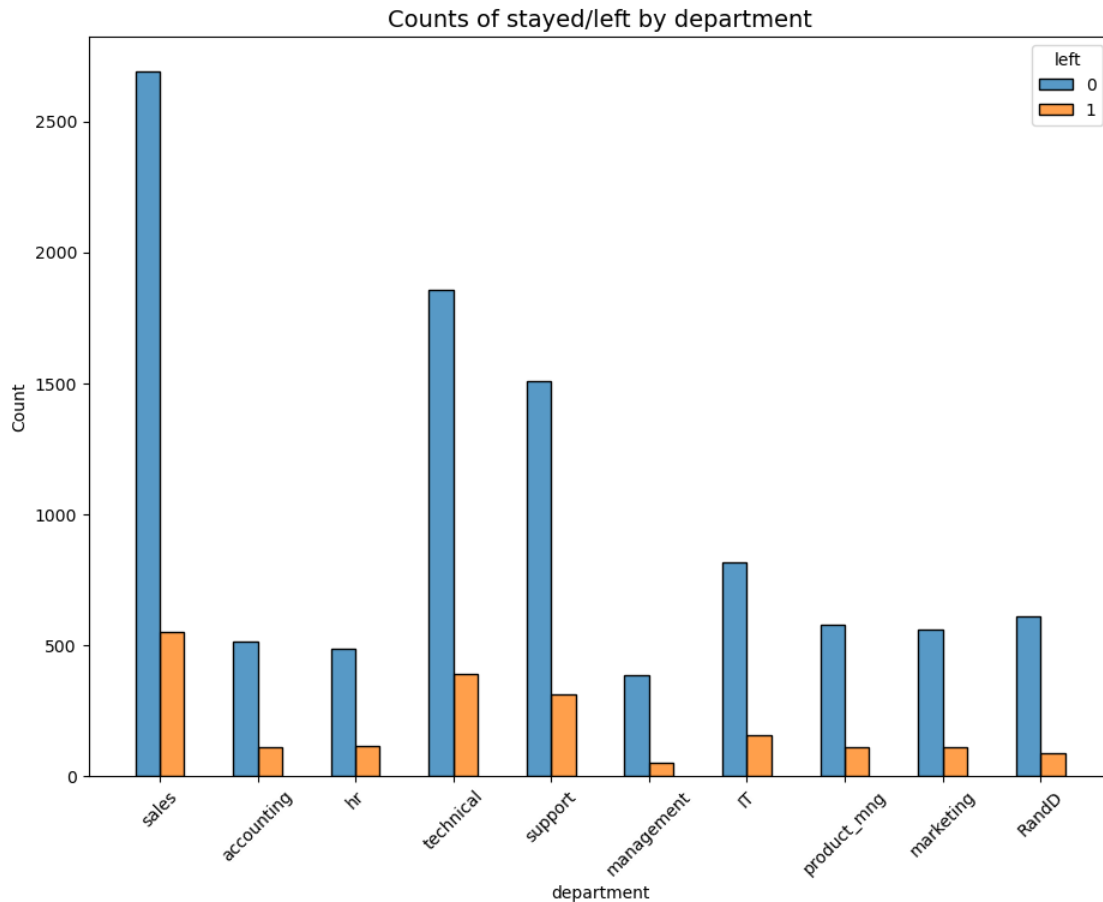
There doesn't seem to be any department that differs significantly in its proportion of employees who left to those who stayed.

Lastly, you could check for strong correlations between variables in the data.

```
[38]: # Plot a correlation heatmap
      plt.figure(figsize=(16, 9))
      heatmap = sns.heatmap(df0.corr(), vmin=-1, vmax=1, annot=True, cmap=sns.
        ↪color_palette("vlag", as_cmap=True))
      heatmap.set_title('Correlation Heatmap', fontdict={'fontsize':14}, pad=12);
```

```
C:\Users\o876\AppData\Local\Temp\ipykernel_20020\736390363.py:3: FutureWarning:
The default value of numeric_only in DataFrame.corr is deprecated. In a future
version, it will default to False. Select only valid columns or specify the
value of numeric_only to silence this warning.
  heatmap = sns.heatmap(df0.corr(), vmin=-1, vmax=1, annot=True,
cmap=sns.color_palette("vlag", as_cmap=True))
```

Correlation Heatmap
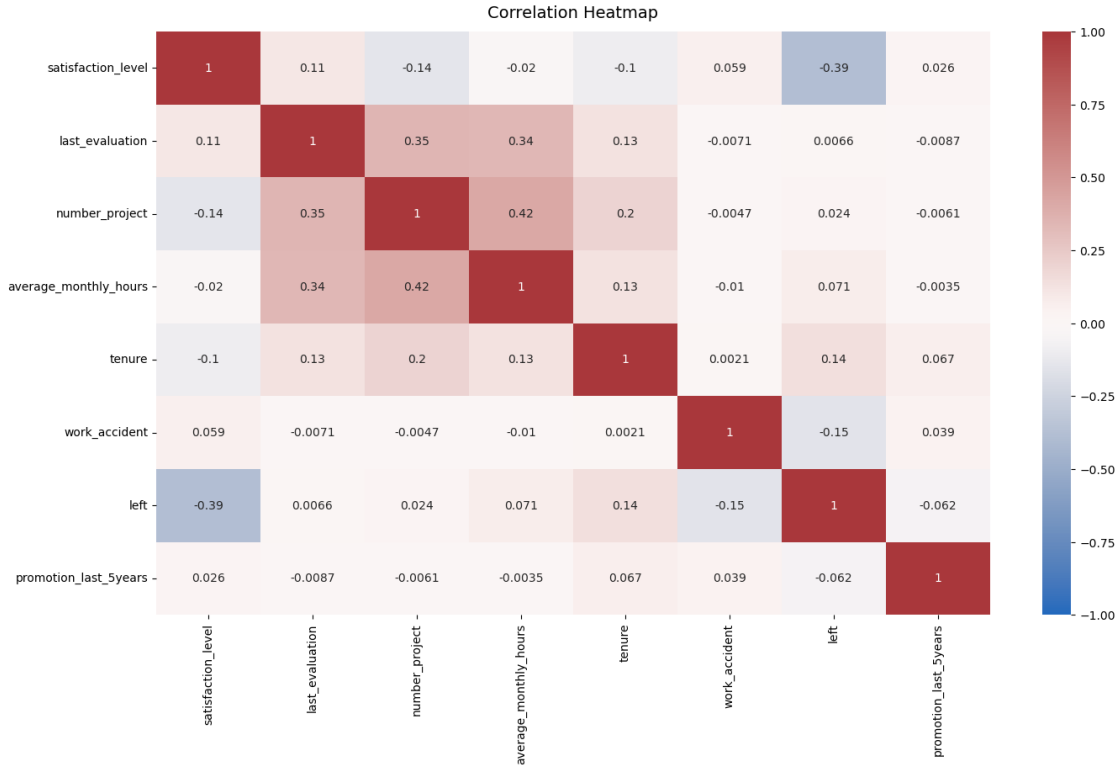
The correlation heatmap confirms that the number of projects, monthly hours, and evaluation scores all have some positive correlation with each other, and whether an employee leaves is negatively correlated with their satisfaction level.

2.1.2 Insights

- It appears that employees are leaving the company as a result of poor management. Leaving is tied to longer working hours, many projects, and generally lower satisfaction levels.
- It can be ungratifying to work long hours and not receive promotions or good evaluation scores.
- There's a sizeable group of employees at this company who are probably burned out.
- It also appears that if an employee has spent more than six years at the company, they tend not to leave.

3 paCe: Construct Stage

- Determine which models are most appropriate
- Construct the model
- Confirm model assumptions

- Evaluate model results to determine how well your model fits the data

3.1 Step 3. Model Building, Step 4. Results and Evaluation

- Fit a model that predicts the outcome variable using two or more independent variables
- Check model assumptions
- Evaluate the model

3.1.1 Identify the type of prediction task.

Your goal is to predict whether an employee leaves the company, which is a categorical outcome variable. So this task involves classification. More specifically, this involves binary classification, since the outcome variable `left` can be either 1 (indicating employee left) or 0 (indicating employee didn't leave).

3.1.2 Identify the types of models most appropriate for this task.

Since the variable you want to predict (whether an employee leaves the company) is categorical, you could either build a Logistic Regression model, or a Tree-based Machine Learning model.

3.1.3 Modeling Approach A: Logistic Regression Model

This approach covers implementation of Logistic Regression.

Logistic regression Note that binomial logistic regression suits the task because it involves binary classification.

Before splitting the data, encode the non-numeric variables. There are two: `department` and `salary`.

`department` is a categorical variable, which means you can dummy it for modeling.

`salary` is categorical too, but it's ordinal. There's a hierarchy to the categories, so it's better not to dummy this column, but rather to convert the levels to numbers, 0–2.

```
[39]: # Copy the dataframe
df_enc = df1.copy()

# Encode the `salary` column as an ordinal numeric category
df_enc['salary'] = (
    df_enc['salary'].astype('category')
    .cat.set_categories(['low', 'medium', 'high'])
```

```
      .cat.codes
)

# Dummy encode the `department` column
df_enc = pd.get_dummies(df_enc, drop_first=False)

# Display the new dataframe
df_enc.head()
```

[39]:
	satisfaction_level	last_evaluation	number_project	average_monthly_hours \
0	0.38	0.53	2	157
1	0.80	0.86	5	262
2	0.11	0.88	7	272
3	0.72	0.87	5	223
4	0.37	0.52	2	159

	tenure	work_accident	left	promotion_last_5years	salary	department_IT \
0	3	0	1	0	0	0
1	6	0	1	0	1	0
2	4	0	1	0	1	0
3	5	0	1	0	0	0
4	3	0	1	0	0	0

	department_RandD	department_accounting	department_hr \
0	0	0	0
1	0	0	0
2	0	0	0
3	0	0	0
4	0	0	0

	department_management	department_marketing	department_product_mng \
0	0	0	0
1	0	0	0
2	0	0	0
3	0	0	0
4	0	0	0

	department_sales	department_support	department_technical
0	1	0	0
1	1	0	0
2	1	0	0
3	1	0	0
4	1	0	0

Create a heatmap to visualize how correlated variables are. Consider which variables you're interested in examining correlations between.

```
[40]:  # Create a heatmap to visualize how correlated variables are
       plt.figure(figsize=(8, 6))
       sns.heatmap(df_enc[['satisfaction_level', 'last_evaluation', 'number_project',␣
         ↪'average_monthly_hours', 'tenure']]
                   .corr(), annot=True, cmap="crest")
       plt.title('Heatmap of the dataset')
       plt.show()
```
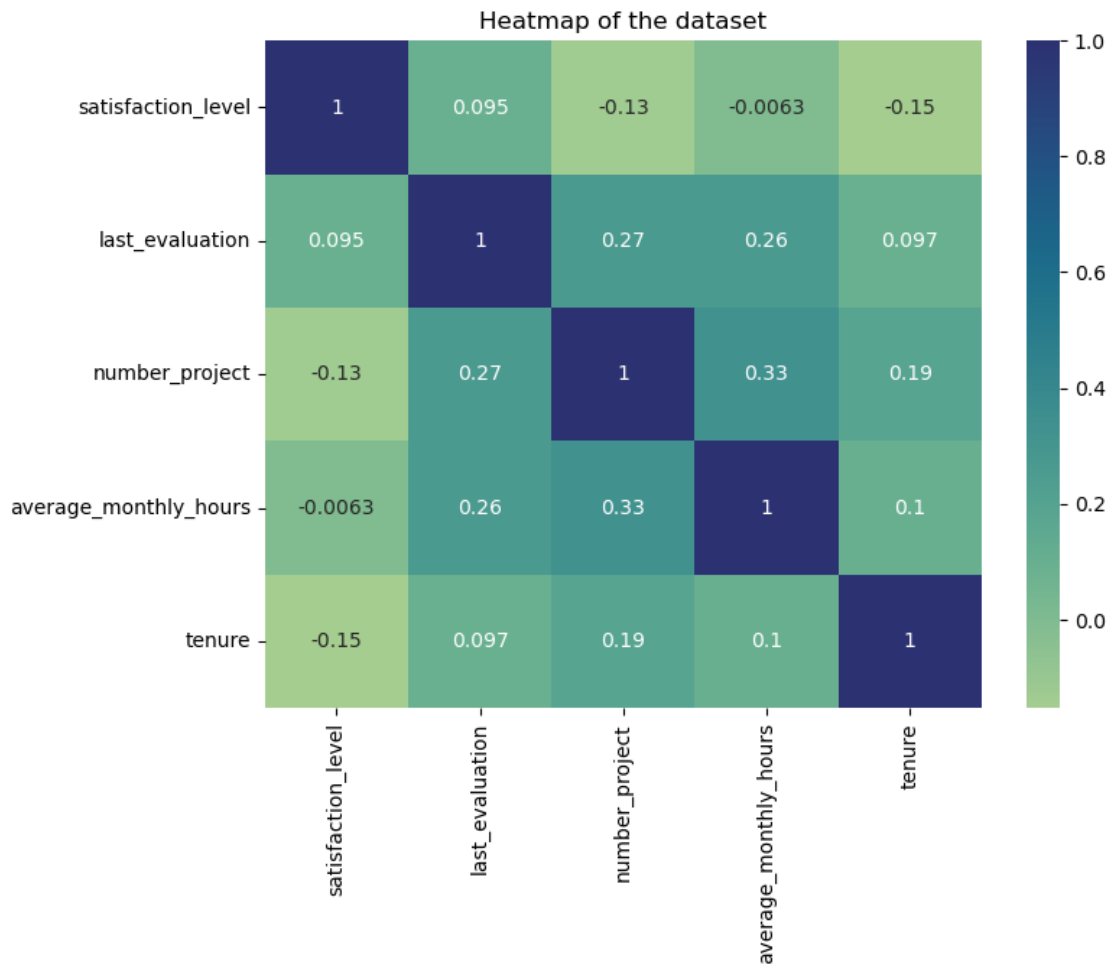

Create a stacked bart plot to visualize number of employees across department, comparing those who left with those who didn't.

```
[41]:  # Create a stacked bart plot to visualize number of employees across␣
         ↪department, comparing those who left with those who didn't
       # In the legend, 0 (purple color) represents employees who did not leave, 1␣
         ↪(red color) represents employees who left
       pd.crosstab(df1['department'], df1['left']).plot(kind ='bar',color='mr')
       plt.title('Counts of employees who left versus stayed across department')
```

```
plt.ylabel('Employee count')
plt.xlabel('Department')
plt.show()
```


Counts of employees who left versus stayed across department
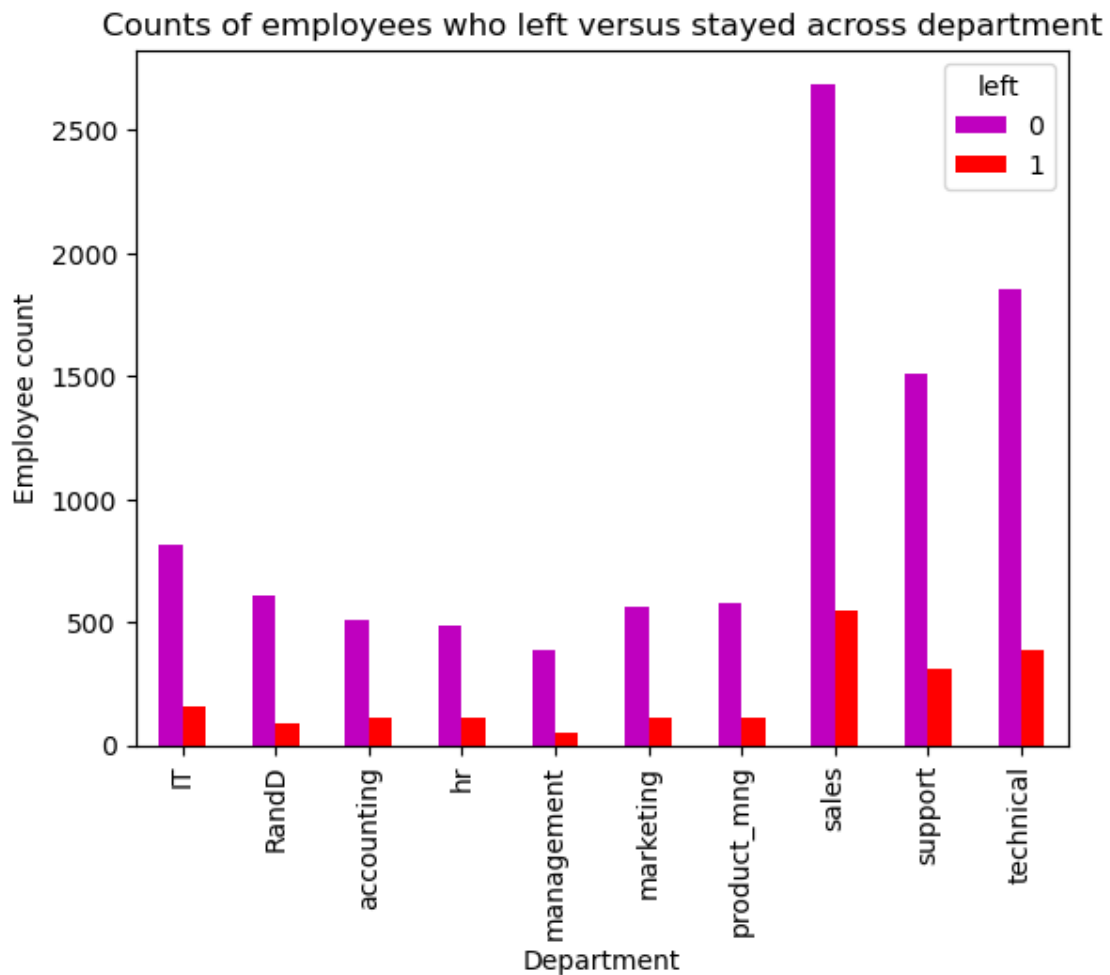
Since logistic regression is quite sensitive to outliers, it would be a good idea at this stage to remove the outliers in the `tenure` column that were identified earlier.

```
[42]:  # Select rows without outliers in `tenure` and save resulting dataframe in a
       ↪new variable
       df_logreg = df_enc[(df_enc['tenure'] >= lower_limit) & (df_enc['tenure'] <=
       ↪upper_limit)]

       # Display first few rows of new dataframe
       df_logreg.head()
```

```
[42]:    satisfaction_level  last_evaluation  number_project  average_monthly_hours  \
    0                 0.38             0.53               2                    157
    2                 0.11             0.88               7                    272
    3                 0.72             0.87               5                    223
    4                 0.37             0.52               2                    159
    5                 0.41             0.50               2                    153

       tenure  work_accident  left  promotion_last_5years  salary  department_IT  \
    0       3              0     1                      0       0              0
    2       4              0     1                      0       1              0
    3       5              0     1                      0       0              0
    4       3              0     1                      0       0              0
    5       3              0     1                      0       0              0

       department_RandD  department_accounting  department_hr  \
    0                 0                      0              0
    2                 0                      0              0
    3                 0                      0              0
    4                 0                      0              0
    5                 0                      0              0

       department_management  department_marketing  department_product_mng  \
    0                     0                      0                       0
    2                     0                      0                       0
    3                     0                      0                       0
    4                     0                      0                       0
    5                     0                      0                       0

       department_sales  department_support  department_technical
    0                 1                   0                     0
    2                 1                   0                     0
    3                 1                   0                     0
    4                 1                   0                     0
    5                 1                   0                     0
```

Isolate the outcome variable, which is the variable you want your model to predict.

```python
[43]: # Isolate the outcome variable
      y = df_logreg['left']

      # Display first few rows of the outcome variable
      y.head()
```

```
[43]: 0    1
      2    1
      3    1
      4    1
      5    1
```

```
Name: left, dtype: int64
```

Select the features you want to use in your model. Consider which variables will help you predict the outcome variable, `left`.

```
[44]: # Select the features you want to use in your model
X = df_logreg.drop('left', axis=1)

# Display the first few rows of the selected features
X.head()
```

```
[44]:    satisfaction_level  last_evaluation  number_project  average_monthly_hours  \
0                    0.38             0.53               2                    157
2                    0.11             0.88               7                    272
3                    0.72             0.87               5                    223
4                    0.37             0.52               2                    159
5                    0.41             0.50               2                    153

   tenure  work_accident  promotion_last_5years  salary  department_IT  \
0       3              0                      0       0              0
2       4              0                      0       1              0
3       5              0                      0       0              0
4       3              0                      0       0              0
5       3              0                      0       0              0

   department_RandD  department_accounting  department_hr  \
0                 0                      0              0
2                 0                      0              0
3                 0                      0              0
4                 0                      0              0
5                 0                      0              0

   department_management  department_marketing  department_product_mng  \
0                      0                     0                       0
2                      0                     0                       0
3                      0                     0                       0
4                      0                     0                       0
5                      0                     0                       0

   department_sales  department_support  department_technical
0                 1                   0                     0
2                 1                   0                     0
3                 1                   0                     0
4                 1                   0                     0
5                 1                   0                     0
```

Split the data into training set and testing set. Don't forget to stratify based on the values in `y`, since the classes are unbalanced.

```
[45]: # Split the data into training set and testing set
      X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.25,␣
      ↪stratify=y, random_state=42)
```

Construct a logistic regression model and fit it to the training dataset.

```
[46]: # Construct a logistic regression model and fit it to the training dataset
      log_clf = LogisticRegression(random_state=42, max_iter=500).fit(X_train,␣
      ↪y_train)
```

Test the logistic regression model: use the model to make predictions on the test set.

```
[47]: # Use the logistic regression model to get predictions on the test set
      y_pred = log_clf.predict(X_test)
```

Create a confusion matrix to visualize the results of the logistic regression model.

```
[48]: # Compute values for confusion matrix
      log_cm = confusion_matrix(y_test, y_pred, labels=log_clf.classes_)

      # Create display of confusion matrix
      log_disp = ConfusionMatrixDisplay(confusion_matrix=log_cm,
                                        display_labels=log_clf.classes_)

      # Plot confusion matrix
      log_disp.plot(values_format='')

      # Display plot
      plt.show()
```
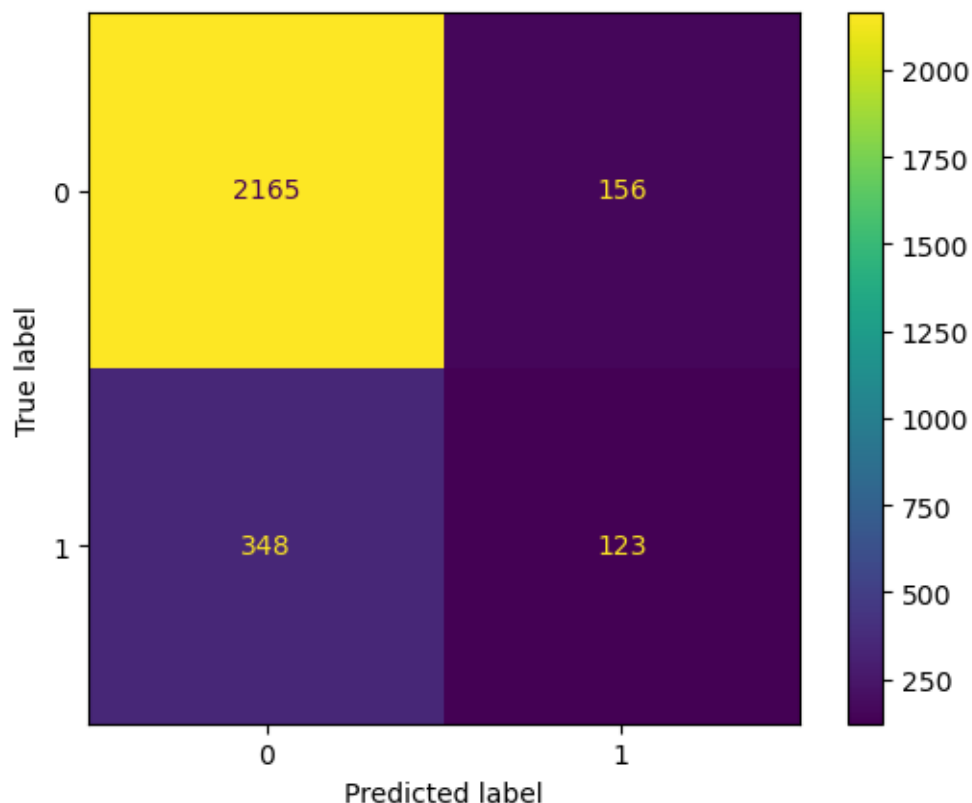
The upper-left quadrant displays the number of true negatives. The upper-right quadrant displays the number of false positives. The bottom-left quadrant displays the number of false negatives. The bottom-right quadrant displays the number of true positives.

True negatives: The number of people who did not leave that the model accurately predicted did not leave.

False positives: The number of people who did not leave the model inaccurately predicted as leaving.

False negatives: The number of people who left that the model inaccurately predicted did not leave

True positives: The number of people who left the model accurately predicted as leaving

A perfect model would yield all true negatives and true positives, and no false negatives or false positives.

Create a classification report that includes precision, recall, f1-score, and accuracy metrics to evaluate the performance of the logistic regression model.

Check the class balance in the data. In other words, check the value counts in the `left` column. Since this is a binary classification task, the class balance informs the way you interpret accuracy metrics.

```
[49]: df_logreg['left'].value_counts(normalize=True)
```

```
[49]: 0    0.831468
      1    0.168532
      Name: left, dtype: float64
```

There is an approximately 83%-17% split. So the data is not perfectly balanced, but it is not too imbalanced. If it was more severely imbalanced, you might want to resample the data to make it more balanced. In this case, you can use this data without modifying the class balance and continue evaluating the model.

```
[50]: # Create classification report for logistic regression model
      target_names = ['Predicted would not leave', 'Predicted would leave']
      print(classification_report(y_test, y_pred, target_names=target_names))
```

	precision	recall	f1-score	support
Predicted would not leave	0.86	0.93	0.90	2321
Predicted would leave	0.44	0.26	0.33	471
accuracy			0.82	2792
macro avg	0.65	0.60	0.61	2792
weighted avg	0.79	0.82	0.80	2792

The classification report above shows that the logistic regression model achieved a precision of 79%, recall of 82%, f1-score of 80% (all weighted averages), and accuracy of 82%. However, if it's most important to predict employees who leave, then the scores are significantly lower.

3.1.4   Modeling Approach B: Tree-based Model

This approach covers implementation of Decision Tree and Random Forest.

Isolate the outcome variable.

```
[51]: # Isolate the outcome variable
      y = df_enc['left']

      # Display the first few rows of `y`
      y.head()
```

```
[51]: 0    1
      1    1
      2    1
      3    1
      4    1
      Name: left, dtype: int64
```

Select the features.

```
[52]: # Select the features
      X = df_enc.drop('left', axis=1)
```

```
# Display the first few rows of `X`
X.head()
```

[52]:

	satisfaction_level	last_evaluation	number_project	average_monthly_hours \
0	0.38	0.53	2	157
1	0.80	0.86	5	262
2	0.11	0.88	7	272
3	0.72	0.87	5	223
4	0.37	0.52	2	159

	tenure	work_accident	promotion_last_5years	salary	department_IT \
0	3	0	0	0	0
1	6	0	0	1	0
2	4	0	0	1	0
3	5	0	0	0	0
4	3	0	0	0	0

	department_RandD	department_accounting	department_hr \
0	0	0	0
1	0	0	0
2	0	0	0
3	0	0	0
4	0	0	0

	department_management	department_marketing	department_product_mng \
0	0	0	0
1	0	0	0
2	0	0	0
3	0	0	0
4	0	0	0

	department_sales	department_support	department_technical
0	1	0	0
1	1	0	0
2	1	0	0
3	1	0	0
4	1	0	0

Split the data into training, validating, and testing sets.

[53]:
```
# Split the data
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.25,␣
 ↪stratify=y, random_state=0)
```

Decision tree - Round 1   Construct a decision tree model and set up cross-validated grid-search to exhuastively search for the best model parameters.

```
[59]:  # Instantiate model
       tree = DecisionTreeClassifier(random_state=0)

       # Assign a dictionary of hyperparameters to search over
       cv_params = {'max_depth':[4, 6, 8, None],
                    'min_samples_leaf': [2, 5, 1],
                    'min_samples_split': [2, 4, 6]
                    }

       # Assign a dictionary of scoring metrics to capture
       scoring = ('accuracy', 'precision', 'recall', 'f1', 'roc_auc')

       # Instantiate GridSearch
       tree1 = GridSearchCV(tree, cv_params, scoring=scoring, cv=4, refit='roc_auc')
```

Fit the decision tree model to the training data.

```
[60]:  %%time
       tree1.fit(X_train, y_train)
```

```
CPU times: total: 6.8 s
Wall time: 6.95 s
```

```
[60]:  GridSearchCV(cv=4, estimator=DecisionTreeClassifier(random_state=0),
                    param_grid={'max_depth': [4, 6, 8, None],
                                'min_samples_leaf': [2, 5, 1],
                                'min_samples_split': [2, 4, 6]},
                    refit='roc_auc',
                    scoring=('accuracy', 'precision', 'recall', 'f1', 'roc_auc'))
```

Identify the optimal values for the decision tree parameters.

```
[61]:  # Check best parameters
       tree1.best_params_
```

```
[61]:  {'max_depth': 4, 'min_samples_leaf': 5, 'min_samples_split': 2}
```

Identify the best AUC score achieved by the decision tree model on the training set.

```
[62]:  # Check best AUC score on CV
       tree1.best_score_
```

```
[62]:  0.969819392792457
```

This is a strong AUC score, which shows that this model can predict employees who will leave very well.

Next, you can write a function that will help you extract all the scores from the grid search.

```python
[63]: def make_results(model_name:str, model_object, metric:str):
          '''
          Arguments:
              model_name (string): what you want the model to be called in the output
          ↪table
              model_object: a fit GridSearchCV object
              metric (string): precision, recall, f1, accuracy, or auc

          Returns a pandas df with the F1, recall, precision, accuracy, and auc scores
          for the model with the best mean 'metric' score across all validation folds.
          ↪
          '''

          # Create dictionary that maps input metric to actual metric name in
          ↪GridSearchCV
          metric_dict = {'auc': 'mean_test_roc_auc',
                         'precision': 'mean_test_precision',
                         'recall': 'mean_test_recall',
                         'f1': 'mean_test_f1',
                         'accuracy': 'mean_test_accuracy'
                        }

          # Get all the results from the CV and put them in a df
          cv_results = pd.DataFrame(model_object.cv_results_)

          # Isolate the row of the df with the max(metric) score
          best_estimator_results = cv_results.iloc[cv_results[metric_dict[metric]].
          ↪idxmax(), :]

          # Extract Accuracy, precision, recall, and f1 score from that row
          auc = best_estimator_results.mean_test_roc_auc
          f1 = best_estimator_results.mean_test_f1
          recall = best_estimator_results.mean_test_recall
          precision = best_estimator_results.mean_test_precision
          accuracy = best_estimator_results.mean_test_accuracy

          # Create table of results
          table = pd.DataFrame()
          table = pd.DataFrame({'model': [model_name],
                                'precision': [precision],
                                'recall': [recall],
                                'F1': [f1],
                                'accuracy': [accuracy],
                                'auc': [auc]
                               })

          return table
```

Use the function just defined to get all the scores from grid search.

```
[64]: # Get all CV scores
      tree1_cv_results = make_results('decision tree cv', tree1, 'auc')
      tree1_cv_results
```

```
[64]:                 model  precision    recall        F1  accuracy       auc
      0  decision tree cv   0.914552  0.916949  0.915707  0.971978  0.969819
```

All of these scores from the decision tree model are strong indicators of good model performance.

Recall that decision trees can be vulnerable to overfitting, and random forests avoid overfitting by incorporating multiple trees to make predictions. You could construct a random forest model next.

Random forest - Round 1   Construct a random forest model and set up cross-validated grid-search to exhaustively search for the best model parameters.

```
[72]: # Instantiate model
      rf = RandomForestClassifier(random_state=0)

      # Assign a dictionary of hyperparameters to search over
      cv_params = {'max_depth': [3,5, None],
                   'max_features': [1.0],
                   'max_samples': [0.7, 1.0],
                   'min_samples_leaf': [1,2,3],
                   'min_samples_split': [2,3,4],
                   'n_estimators': [ 500],
                   }

      # Assign a dictionary of scoring metrics to capture
      scoring = ('accuracy', 'precision', 'recall', 'f1', 'roc_auc')

      # Instantiate GridSearch
      rf1 = GridSearchCV(rf, cv_params, scoring=scoring, cv=4, refit='roc_auc')
```

Fit the random forest model to the training data.

```
[73]: %%time
      rf1.fit(X_train, y_train) # --> Wall time: ~10min
```

```
CPU times: total: 31min 7s
Wall time: 31min 21s
```

```
[73]: GridSearchCV(cv=4, estimator=RandomForestClassifier(random_state=0),
                   param_grid={'max_depth': [3, 5, None], 'max_features': [1.0],
                               'max_samples': [0.7, 1.0],
                               'min_samples_leaf': [1, 2, 3],
                               'min_samples_split': [2, 3, 4],
                               'n_estimators': [500]},
                   refit='roc_auc',
```

```
                scoring=('accuracy', 'precision', 'recall', 'f1', 'roc_auc'))
```

Specify path to where you want to save your model.

```python
[98]:  # Define a path to the folder where you want to save the model
       path = '/Users/o876/Desktop/'
```

Define functions to pickle the model and read in the model.

```python
[99]:  def write_pickle(path, model_object, save_as:str):
           '''
           In:
               path:         path of folder where you want to save the pickle
               model_object: a model you want to pickle
               save_as:      filename for how you want to save the model

           Out: A call to pickle the model in the folder indicated
           '''

           with open(path + save_as + '.pickle', 'wb') as to_write:
               pickle.dump(model_object, to_write)
```

```python
[100]: def read_pickle(path, saved_model_name:str):
           '''
           In:
               path:             path to folder where you want to read from
               saved_model_name: filename of pickled model you want to read in

           Out:
               model: the pickled model
           '''
           with open(path + saved_model_name + '.pickle', 'rb') as to_read:
               model = pickle.load(to_read)

           return model
```

Use the functions defined above to save the model in a pickle file and then read it in.

```python
[101]: # Write pickle
       write_pickle(path, rf1, 'hr_rf1')
```

```python
[102]: # Read pickle
       rf1 = read_pickle(path, 'hr_rf1')
```

Identify the best AUC score achieved by the random forest model on the training set.

```python
[103]: # Check best AUC score on CV
       rf1.best_score_
```

[103]: 0.9804250949807172

Identify the optimal values for the parameters of the random forest model.

```
[104]:  # Check best params
        rf1.best_params_
```

```
[104]:  {'max_depth': 5,
         'max_features': 1.0,
         'max_samples': 0.7,
         'min_samples_leaf': 1,
         'min_samples_split': 4,
         'n_estimators': 500}
```

Collect the evaluation scores on the training set for the decision tree and random forest models.

```
[105]:  # Get all CV scores
        rf1_cv_results = make_results('random forest cv', rf1, 'auc')
        print(tree1_cv_results)
        print(rf1_cv_results)
```

	model	precision	recall	F1	accuracy	auc
0	decision tree cv	0.914552	0.916949	0.915707	0.971978	0.969819

	model	precision	recall	F1	accuracy	auc
0	random forest cv	0.950023	0.915614	0.932467	0.977983	0.980425

The evaluation scores of the random forest model are better than those of the decision tree model, with the exception of recall (the recall score of the random forest model is approximately 0.001 lower, which is a negligible amount). This indicates that the random forest model mostly outperforms the decision tree model.

Next, you can evaluate the final model on the test set.

Define a function that gets all the scores from a model's predictions.

```
[106]:  def get_scores(model_name:str, model, X_test_data, y_test_data):
            '''
            Generate a table of test scores.

            In:
                model_name (string):   How you want your model to be named in the output␣
            ↪table
                model:                 A fit GridSearchCV object
                X_test_data:           numpy array of X_test data
                y_test_data:           numpy array of y_test data

            Out: pandas df of precision, recall, f1, accuracy, and AUC scores for your␣
            ↪model
            '''
```

```
        preds = model.best_estimator_.predict(X_test_data)

        auc = roc_auc_score(y_test_data, preds)
        accuracy = accuracy_score(y_test_data, preds)
        precision = precision_score(y_test_data, preds)
        recall = recall_score(y_test_data, preds)
        f1 = f1_score(y_test_data, preds)

        table = pd.DataFrame({'model': [model_name],
                              'precision': [precision],
                              'recall': [recall],
                              'f1': [f1],
                              'accuracy': [accuracy],
                              'AUC': [auc]
                             })

        return table
```

Now use the best performing model to predict on the test set.

[107]:
```
# Get predictions on test data
rf1_test_scores = get_scores('random forest1 test', rf1, X_test, y_test)
rf1_test_scores
```

[107]:

	model	precision	recall	f1	accuracy	AUC
0	random forest1 test	0.964211	0.919679	0.941418	0.980987	0.956439

The test scores are very similar to the validation scores, which is good. This appears to be a strong model. Since this test set was only used for this model, you can be more confident that your model's performance on this data is representative of how it will perform on new, unseeen data.

Feature Engineering   You might be skeptical of the high evaluation scores. There is a chance that there is some data leakage occurring. Data leakage is when you use data to train your model that should not be used during training, either because it appears in the test data or because it's not data that you'd expect to have when the model is actually deployed. Training a model with leaked data can give an unrealistic score that is not replicated in production.

In this case, it's likely that the company won't have satisfaction levels reported for all of its employees. It's also possible that the `average_monthly_hours` column is a source of some data leakage. If employees have already decided upon quitting, or have already been identified by management as people to be fired, they may be working fewer hours.

The first round of decision tree and random forest models included all variables as features. This next round will incorporate feature engineering to build improved models.

You could proceed by dropping `satisfaction_level` and creating a new feature that roughly captures whether an employee is overworked. You could call this new feature `overworked`. It will be a binary variable.

```
[108]:  # Drop `satisfaction_level` and save resulting dataframe in new variable
        df2 = df_enc.drop('satisfaction_level', axis=1)

        # Display first few rows of new dataframe
        df2.head()
```

```
[108]:     last_evaluation  number_project  average_monthly_hours  tenure  \
        0             0.53               2                    157       3
        1             0.86               5                    262       6
        2             0.88               7                    272       4
        3             0.87               5                    223       5
        4             0.52               2                    159       3

           work_accident  left  promotion_last_5years  salary  department_IT  \
        0              0     1                      0       0              0
        1              0     1                      0       1              0
        2              0     1                      0       1              0
        3              0     1                      0       0              0
        4              0     1                      0       0              0

           department_RandD  department_accounting  department_hr  \
        0                 0                      0              0
        1                 0                      0              0
        2                 0                      0              0
        3                 0                      0              0
        4                 0                      0              0

           department_management  department_marketing  department_product_mng  \
        0                      0                     0                       0
        1                      0                     0                       0
        2                      0                     0                       0
        3                      0                     0                       0
        4                      0                     0                       0

           department_sales  department_support  department_technical
        0                 1                   0                     0
        1                 1                   0                     0
        2                 1                   0                     0
        3                 1                   0                     0
        4                 1                   0                     0
```

```
[109]:  # Create `overworked` column. For now, it's identical to average monthly hours.
        df2['overworked'] = df2['average_monthly_hours']

        # Inspect max and min average monthly hours values
        print('Max hours:', df2['overworked'].max())
        print('Min hours:', df2['overworked'].min())
```

```
Max hours: 310
Min hours: 96
```

166.67 is approximately the average number of monthly hours for someone who works 50 weeks per year, 5 days per week, 8 hours per day.

You could define being overworked as working more than 175 hours per month on average.

To make the `overworked` column binary, you could reassign the column using a boolean mask. - `df3['overworked'] > 175` creates a series of booleans, consisting of `True` for every value > 175 and `False` for every values   175 - `.astype(int)` converts all `True` to 1 and all `False` to 0

```
[110]:  # Define `overworked` as working > 175 hrs/week
        df2['overworked'] = (df2['overworked'] > 175).astype(int)

        # Display first few rows of new column
        df2['overworked'].head()
```

```
[110]: 0    0
       1    1
       2    1
       3    1
       4    0
       Name: overworked, dtype: int32
```

Drop the `average_monthly_hours` column.

```
[111]:  # Drop the `average_monthly_hours` column
        df2 = df2.drop('average_monthly_hours', axis=1)

        # Display first few rows of resulting dataframe
        df2.head()
```

```
[111]:    last_evaluation  number_project  tenure  work_accident  left  \
       0             0.53               2       3              0     1
       1             0.86               5       6              0     1
       2             0.88               7       4              0     1
       3             0.87               5       5              0     1
       4             0.52               2       3              0     1

          promotion_last_5years  salary  department_IT  department_RandD  \
       0                      0       0              0                 0
       1                      0       1              0                 0
       2                      0       1              0                 0
       3                      0       0              0                 0
       4                      0       0              0                 0

          department_accounting  department_hr  department_management  \
       0                      0              0                      0
       1                      0              0                      0
```

	department_marketing	department_product_mng	department_sales	\
2	0	0	0	
3	0	0	0	
4	0	0	0	

	department_marketing	department_product_mng	department_sales	\
0	0	0	1	
1	0	0	1	
2	0	0	1	
3	0	0	1	
4	0	0	1	

	department_support	department_technical	overworked
0	0	0	0
1	0	0	1
2	0	0	1
3	0	0	1
4	0	0	0

Again, isolate the features and target variables

```
[112]: # Isolate the outcome variable
y = df2['left']

# Select the features
X = df2.drop('left', axis=1)
```

Split the data into training and testing sets.

```
[113]: # Create test data
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.25,
 ↪stratify=y, random_state=0)
```

Decision tree - Round 2

```
[116]: # Instantiate model
tree = DecisionTreeClassifier(random_state=0)

# Assign a dictionary of hyperparameters to search over
cv_params = {'max_depth':[4, 6, 8, None],
            'min_samples_leaf': [2, 5, 1],
            'min_samples_split': [2, 4, 6]
            }

# Assign a dictionary of scoring metrics to capture
scoring = ('accuracy', 'precision', 'recall', 'f1', 'roc_auc')

# Instantiate GridSearch
tree2 = GridSearchCV(tree, cv_params, scoring=scoring, cv=4, refit='roc_auc')
```

```
[118]: %%time
       tree2.fit(X_train, y_train)
```

```
CPU times: total: 6.84 s
Wall time: 7.31 s
```

```
[118]: GridSearchCV(cv=4, estimator=DecisionTreeClassifier(random_state=0),
                    param_grid={'max_depth': [4, 6, 8, None],
                                'min_samples_leaf': [2, 5, 1],
                                'min_samples_split': [2, 4, 6]},
                    refit='roc_auc',
                    scoring=('accuracy', 'precision', 'recall', 'f1', 'roc_auc'))
```

```
[119]: # Check best params
       tree2.best_params_
```

```
[119]: {'max_depth': 6, 'min_samples_leaf': 2, 'min_samples_split': 6}
```

```
[120]: # Check best AUC score on CV
       tree2.best_score_
```

```
[120]: 0.9586752505340426
```

This model performs very well, even without satisfaction levels and detailed hours worked data.

Next, check the other scores.

```
[121]: # Get all CV scores
       tree2_cv_results = make_results('decision tree2 cv', tree2, 'auc')
       print(tree1_cv_results)
       print(tree2_cv_results)
```

```
              model  precision    recall       F1  accuracy       auc
0   decision tree cv   0.914552  0.916949  0.915707  0.971978  0.969819
              model  precision    recall       F1  accuracy       auc
0  decision tree2 cv   0.856693  0.903553  0.878882  0.958523  0.958675
```

Some of the other scores fell. That's to be expected given fewer features were taken into account in this round of the model. Still, the scores are very good.

Random forest - Round 2

```
[123]: # Instantiate model
       rf = RandomForestClassifier(random_state=0)

       # Assign a dictionary of hyperparameters to search over
       cv_params = {'max_depth': [3,5, None],
                    'max_features': [1.0],
                    'max_samples': [0.7, 1.0],
                    'min_samples_leaf': [1,2,3],
                    'min_samples_split': [2,3,4],
```

```
                    'n_estimators': [300],
                    }

# Assign a dictionary of scoring metrics to capture
scoring = ('accuracy', 'precision', 'recall', 'f1', 'roc_auc')

# Instantiate GridSearch
rf2 = GridSearchCV(rf, cv_params, scoring=scoring, cv=4, refit='roc_auc')
```

[124]:
```
%%time
rf2.fit(X_train, y_train) # --> Wall time: 7min 5s
```

```
CPU times: total: 13min 6s
Wall time: 13min 11s
```

[124]:
```
GridSearchCV(cv=4, estimator=RandomForestClassifier(random_state=0),
             param_grid={'max_depth': [3, 5, None], 'max_features': [1.0],
                         'max_samples': [0.7, 1.0],
                         'min_samples_leaf': [1, 2, 3],
                         'min_samples_split': [2, 3, 4],
                         'n_estimators': [300]},
             refit='roc_auc',
             scoring=('accuracy', 'precision', 'recall', 'f1', 'roc_auc'))
```

[125]:
```
# Write pickle
write_pickle(path, rf2, 'hr_rf2')
```

[126]:
```
# Read in pickle
rf2 = read_pickle(path, 'hr_rf2')
```

[127]:
```
# Check best params
rf2.best_params_
```

[127]:
```
{'max_depth': 5,
 'max_features': 1.0,
 'max_samples': 0.7,
 'min_samples_leaf': 2,
 'min_samples_split': 2,
 'n_estimators': 300}
```

[128]:
```
# Check best AUC score on CV
rf2.best_score_
```

[128]: 0.9648100662833985

[129]:
```
# Get all CV scores
rf2_cv_results = make_results('random forest2 cv', rf2, 'auc')
print(tree2_cv_results)
```

```
print(rf2_cv_results)
```

```
              model  precision    recall        F1  accuracy       auc
0  decision tree2 cv   0.856693  0.903553  0.878882  0.958523  0.958675
              model  precision    recall        F1  accuracy       auc
0  random forest2 cv   0.866758  0.878754  0.872407  0.957411   0.96481
```

Again, the scores dropped slightly, but the random forest performs better than the decision tree if using AUC as the deciding metric.

Score the champion model on the test set now.

[130]:
```python
# Get predictions on test data
rf2_test_scores = get_scores('random forest2 test', rf2, X_test, y_test)
rf2_test_scores
```

[130]:
```
              model  precision    recall      f1  accuracy       AUC
0  random forest2 test   0.870406  0.903614  0.8867  0.961641  0.938407
```

This seems to be a stable, well-performing final model.

Plot a confusion matrix to visualize how well it predicts on the test set.

[131]:
```python
# Generate array of values for confusion matrix
preds = rf2.best_estimator_.predict(X_test)
cm = confusion_matrix(y_test, preds, labels=rf2.classes_)

# Plot confusion matrix
disp = ConfusionMatrixDisplay(confusion_matrix=cm,
                              display_labels=rf2.classes_)
disp.plot(values_format='');
```
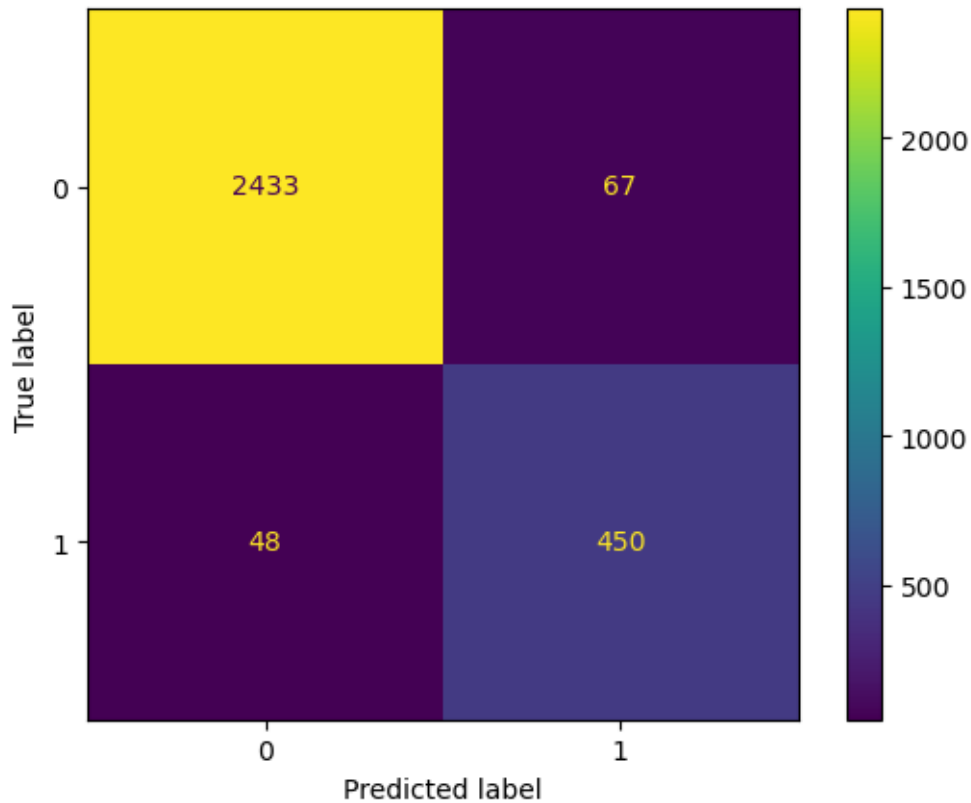
The model predicts more false positives than false negatives, which means that some employees may be identified as at risk of quitting or getting fired, when that's actually not the case. But this is still a strong model.

For exploratory purpose, you might want to inspect the splits of the decision tree model and the most important features in the random forest model.

Decision tree feature importance You can also get feature importance from decision trees (see the DecisionTreeClassifier scikit-learn documentation for details).

```
[136]:  #tree2_importances = pd.DataFrame(tree2.best_estimator_.feature_importances_,
        ↪columns=X.columns)
        tree2_importances = pd.DataFrame(tree2.best_estimator_.feature_importances_,
                                         columns=['gini_importance'],
                                         index=X.columns
                                         )
        tree2_importances = tree2_importances.sort_values(by='gini_importance',
         ↪ascending=False)

        # Only extract the features with importances > 0
        tree2_importances = tree2_importances[tree2_importances['gini_importance'] != 0]
        tree2_importances
```

```
[136]:                          gini_importance
        last_evaluation              0.343958
        number_project               0.343385
        tenure                        0.215681
        overworked                    0.093498
        department_support            0.001142
        salary                        0.000910
        department_sales              0.000607
        department_technical          0.000418
        work_accident                 0.000183
        department_IT                 0.000139
        department_marketing          0.000078
```

You can then create a barplot to visualize the decision tree feature importances.

```
[137]:  sns.barplot(data=tree2_importances, x="gini_importance", y=tree2_importances.
         ↪index, orient='h')
        plt.title("Decision Tree: Feature Importances for Employee Leaving",␣
         ↪fontsize=12)
        plt.ylabel("Feature")
        plt.xlabel("Importance")
        plt.show()
```


The barplot above shows that in this decision tree model, `last_evaluation`, `number_project`, `tenure`, and `overworked` have the highest importance, in that order. These variables are most

helpful in predicting the outcome variable, `left`.

Random forest feature importance Now, plot the feature importances for the random forest model.

```
[138]: # Get feature importances
       feat_impt = rf2.best_estimator_.feature_importances_

       # Get indices of top 10 features
       ind = np.argpartition(rf2.best_estimator_.feature_importances_, -10)[-10:]

       # Get column labels of top 10 features
       feat = X.columns[ind]

       # Filter `feat_impt` to consist of top 10 feature importances
       feat_impt = feat_impt[ind]

       y_df = pd.DataFrame({"Feature":feat,"Importance":feat_impt})
       y_sort_df = y_df.sort_values("Importance")
       fig = plt.figure()
       ax1 = fig.add_subplot(111)

       y_sort_df.plot(kind='barh',ax=ax1,x="Feature",y="Importance")

       ax1.set_title("Random Forest: Feature Importances for Employee Leaving",␣
        ↪fontsize=12)
       ax1.set_ylabel("Feature")
       ax1.set_xlabel("Importance")

       plt.show()
```
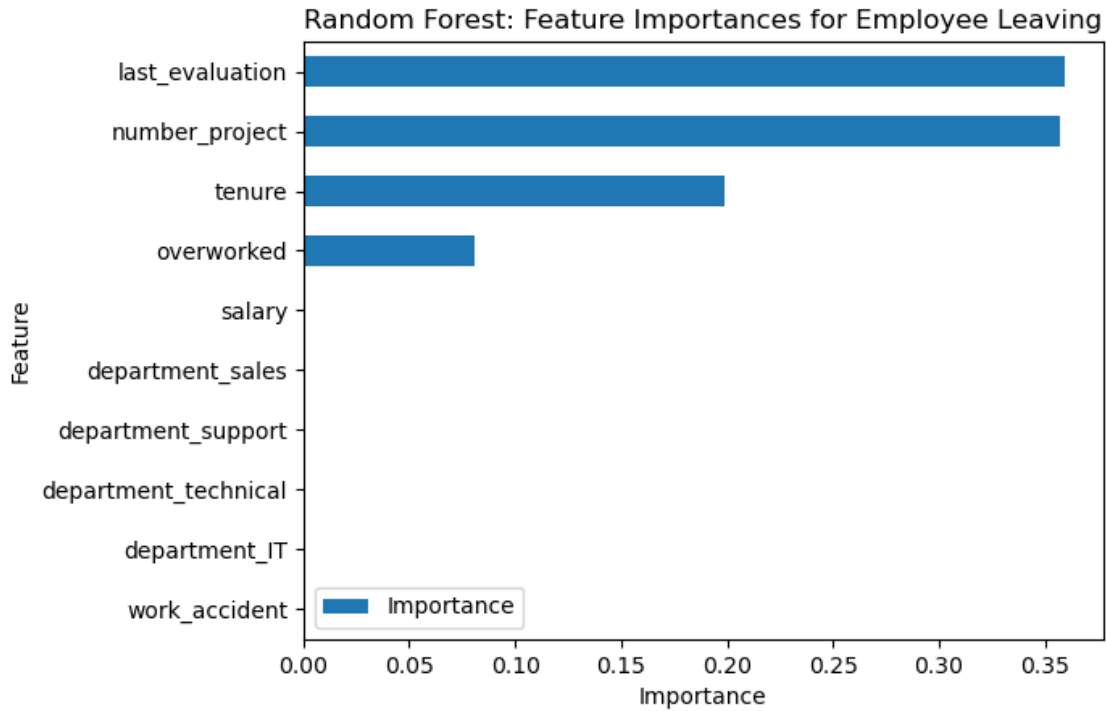
Random Forest: Feature Importances for Employee Leaving

The plot above shows that in this random forest model, `last_evaluation`, `number_project`, `tenure`, and `overworked` have the highest importance, in that order. These variables are most helpful in predicting the outcome variable, `left`, and they are the same as the ones used by the decision tree model.

4 pacE: Execute Stage

- Interpret model performance and results
- Share actionable steps with stakeholders

Evaluation metrics

- **AUC** is the area under the ROC curve; it's also considered the probability that the model ranks a random positive example more highly than a random negative example.
- **Precision** measures the proportion of data points predicted as True that are actually True, in other words, the proportion of positive predictions that are true positives.
- **Recall** measures the proportion of data points that are predicted as True, out of all the data points that are actually True. In other words, it measures the proportion of positives that are correctly classified.
- **Accuracy** measures the proportion of data points that are correctly classified.
- **F1-score** is an aggregation of precision and recall.

4.1 Step 4. Results and Evaluation

- Interpret model

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- Evaluate model performance using metrics
- Prepare results, visualizations, and actionable steps to share with stakeholders

4.1.1 Summary of model results

Logistic Regression

The logistic regression model achieved precision of 80%, recall of 83%, f1-score of 80% (all weighted averages), and accuracy of 83%, on the test set.

Tree-based Machine Learning

After conducting feature engineering, the decision tree model achieved AUC of 93.8%, precision of 87.0%, recall of 90.4%, f1-score of 88.7%, and accuracy of 96.2%, on the test set. The random forest modestly outperformed the decision tree model.

4.1.2 Conclusion, Recommendations, Next Steps

The models and the feature importances extracted from the models confirm that employees at the company are overworked.

To retain employees, the following recommendations could be presented to the stakeholders:

- Cap the number of projects that employees can work on.
- Consider promoting employees who have been with the company for atleast four years, or conduct further investigation about why four-year tenured employees are so dissatisfied.
- Either reward employees for working longer hours, or don't require them to do so.
- If employees aren't familiar with the company's overtime pay policies, inform them about this. If the expectations around workload and time off aren't explicit, make them clear.
- Hold company-wide and within-team discussions to understand and address the company work culture, across the board and in specific contexts.
- High evaluation scores should not be reserved for employees who work 200+ hours per month. Consider a proportionate scale for rewarding employees who contribute more/put in more effort.