Capstone project: Providing data-driven suggestions for HR

Description and deliverables

This capstone project is an opportunity for you to analyze a dataset and build predictive models that can provide insights to the Human Resources (HR) department of a large consulting firm.

Upon completion, you will have two artifacts that you would be able to present to future employers. One is a brief one-page summary (https://docs.google.com/presentation/d/1Pps5GKxi1V31y2oRHRzU-xhJubkEYzCgEIfNjlEY3Og/template/preview#slide=id.g1c07b9724f3_0_983) of this project that you would present to external stakeholders as the data professional in Salifort Motors. The other is a complete code notebook provided here. Please consider your prior course work and select one way to achieve this given project question. Either use a regression model or machine learning model to predict whether or not an employee will leave the company. The exemplar following this actiivty shows both approaches, but you only need to do one.

In your deliverables, you will include the model evaluation (and interpretation if applicable), a data visualization(s) of your choice that is directly related to the question you ask, ethical considerations, and the resources you used to troubleshoot and find answers or solutions.

PACE stages

- Plan
- Analyze
- Construct
- Execute

Pace: Plan Stage

- Understand your data in the problem context
- Consider how your data will best address the business need
- Contextualize & understand the data and the problem

Understand the business scenario and problem

The HR department at Salifort Motors wants to take some initiatives to improve employee satisfaction levels at the company. They collected data from employees, but now they don't know what to do with it. They refer to you as a data analytics professional and ask you to provide data-driven suggestions based on your understanding of the data. They have the following question: what's likely to make the employee leave the company?

Your goals in this project are to analyze the data collected by the HR department and to build a model that predicts whether or not an employee will leave the company.

If you can predict employees likely to quit, it might be possible to identify factors that contribute to their leaving. Because it is time-consuming and expensive to find, interview, and hire new employees, increasing employee retention will be beneficial to the company.

Familiarize yourself with the HR dataset

In this dataset (https://www.kaggle.com/datasets/mfaisalqureshi/hr-analytics-and-job-prediction?select=HR_comma_sep.csv), 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)

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?

Step 1. Imports

- Import packages
- Load dataset

Import packages

In [1]:

```
# Import packages
### YOUR CODE HERE ###

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

# For data visualization
%matplotlib inline
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
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
```

Load dataset

In [2]:
```
# Load dataset into a dataframe
### YOUR CODE HERE ###
df0 = pd.read_csv("HR_capstone_dataset.csv")

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

Out[2]:

	satisfaction_level	last_evaluation	number_project	average_montly_hours	time_spend_company	Work_a
0	0.38	0.53	2	157	3	
1	0.80	0.86	5	262	6	
2	0.11	0.88	7	272	4	
3	0.72	0.87	5	223	5	
4	0.37	0.52	2	159	3	

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

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

Gather basic information about the data

In [3]:
```
# Gather basic information about the data
### YOUR CODE HERE ###
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
```

Gather descriptive statistics about the data

In [4]:
```
# Gather descriptive statistics about the data
### YOUR CODE HERE ###
df0.describe()
```

Out[4]:

	satisfaction_level	last_evaluation	number_project	average_montly_hours	time_spend_company	Wo
count	14999.000000	14999.000000	14999.000000	14999.000000	14999.000000	1
mean	0.612834	0.716102	3.803054	201.050337	3.498233	
std	0.248631	0.171169	1.232592	49.943099	1.460136	
min	0.090000	0.360000	2.000000	96.000000	2.000000	
25%	0.440000	0.560000	3.000000	156.000000	3.000000	
50%	0.640000	0.720000	4.000000	200.000000	3.000000	
75%	0.820000	0.870000	5.000000	245.000000	4.000000	
max	1.000000	1.000000	7.000000	310.000000	10.000000	

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.

In [5]:
```
# Display all column names
### YOUR CODE HERE ###
df0.columns
```

Out[5]:
```
Index(['satisfaction_level', 'last_evaluation', 'number_project',
       'average_montly_hours', 'time_spend_company', 'Work_accident', 'left',
       'promotion_last_5years', 'Department', 'salary'],
      dtype='object')
```

In [6]:
```
# Rename columns as needed
### YOUR CODE HERE ###
df0 = df0.rename(columns={'Work_accident': 'work_accident',
                          'average_montly_hours': 'average_monthly_hours',
                          'time_spend_company': 'tenure',
                          'Department': 'department'})

# Display all column names after the update
### YOUR CODE HERE ###
df0.columns
```

Out[6]:
```
Index(['satisfaction_level', 'last_evaluation', 'number_project',
       'average_monthly_hours', 'tenure', 'work_accident', 'left',
       'promotion_last_5years', 'department', 'salary'],
      dtype='object')
```

Check missing values

Check for any missing values in the data.

In [7]:
```
# Check for missing values
### YOUR CODE HERE ###
df0.isna().sum()
```

Out[7]:
```
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.

Check duplicates

Check for any duplicate entries in the data.

In [8]:
```
# Check for duplicates
### YOUR CODE HERE ###
df0.duplicated().sum()
```

Out[8]:
```
3008
```

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

In [9]:
```
# Inspect some rows containing duplicates as needed
### YOUR CODE HERE ###
df0[df0.duplicated()].head()
```

Out[9]:

	satisfaction_level	last_evaluation	number_project	average_monthly_hours	tenure	work_accident	le
396	0.46	0.57	2	139	3	0	
866	0.41	0.46	2	128	3	0	
1317	0.37	0.51	2	127	3	0	
1368	0.41	0.52	2	132	3	0	
1461	0.42	0.53	2	142	3	0	

The above output shows the first five occurences of rows that are duplicated farther down in the dataframe. How likely is it that these are legitimate entries? In other words, how plausible is it that two employees self-reported the exact same response for every column?

You could perform a likelihood analysis by essentially applying Bayes' theorem and multiplying the probabilities of finding each value in each column, but this does not seem necessary. With several continuous variables across 10 columns, it seems very unlikely that these observations are legitimate. You can proceed by dropping them.

In [10]:
```
# Drop duplicates and save resulting dataframe in a new variable as needed
### YOUR CODE HERE ###
df1 = df0.drop_duplicates(keep='first')

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

Out[10]:

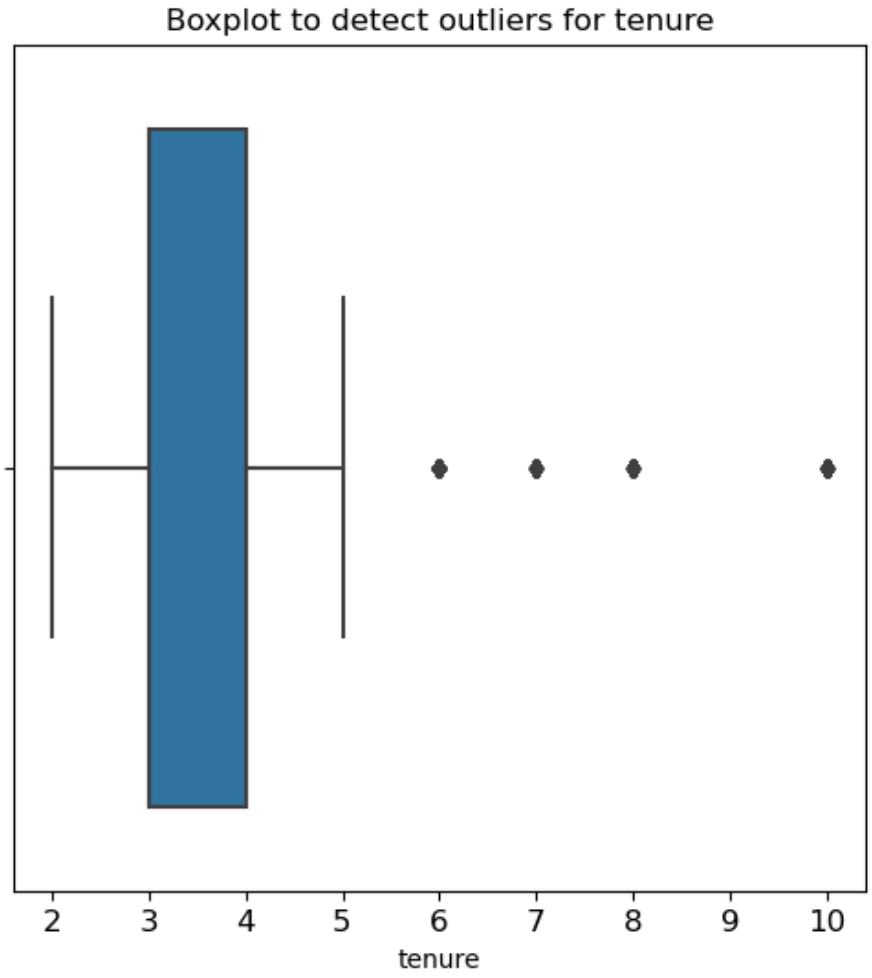
	satisfaction_level	last_evaluation	number_project	average_monthly_hours	tenure	work_accident	left
0	0.38	0.53	2	157	3	0	1
1	0.80	0.86	5	262	6	0	1
2	0.11	0.88	7	272	4	0	1
3	0.72	0.87	5	223	5	0	1
4	0.37	0.52	2	159	3	0	1

Check outliers

Check for outliers in the data.

In [11]:

```
# 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()
```



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.

In [12]:

```
# Determine the number of rows containing outliers
### YOUR CODE HERE ###

# 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.

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?

Step 2. Data Exploration (Continue EDA)

Data visualizations

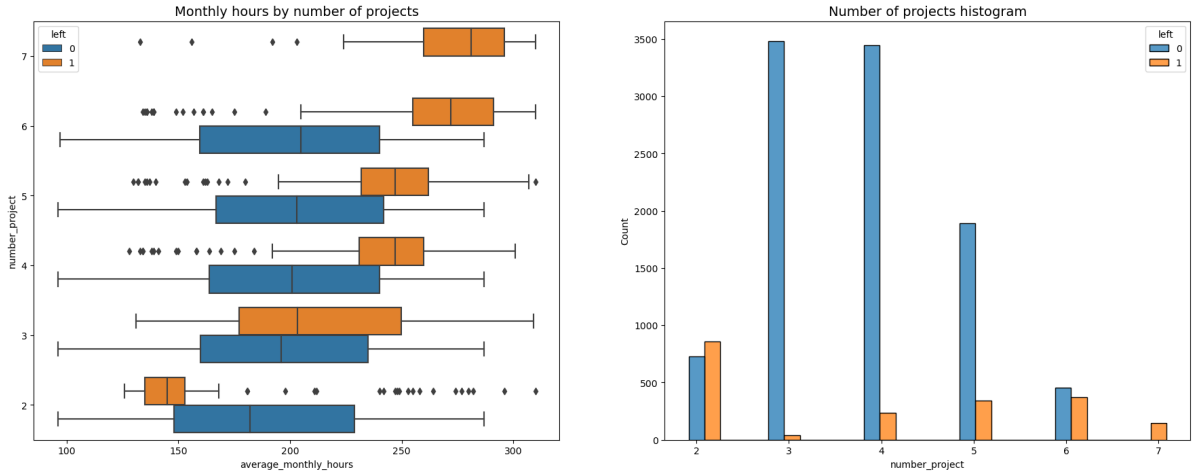
Now, start examining the variables that you're interested in, and create plots to visualize relationships between variables in the data.

You could start by creating a stacked boxplot showing `average_monthly_hours` distributions for `number_project`, comparing the distributions of employees who stayed versus those who left.

Box plots are very useful in visualizing distributions within data, but they can be deceiving without the context of how big the sample sizes that they represent are. So, you could also plot a stacked histogram to visualize the distribution of `number_project` for those who stayed and those who left.

In [13]:

```
# Create a plot as needed
### YOUR CODE HERE ###

# Set figure and axes
fig, ax = plt.subplots(1, 2, figsize = (22,8))

# Create boxplot showing `average_monthly_hours` distributions for `number_projec
sns.boxplot(data=df1, x='average_monthly_hours', y='number_project', hue='left', 
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 
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[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/week—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, you could confirm that all employees with seven projects left.

In [14]:
```
# Get value counts of stayed/left for employees with 7 projects
df1[df1['number_project']==7]['left'].value_counts()
```

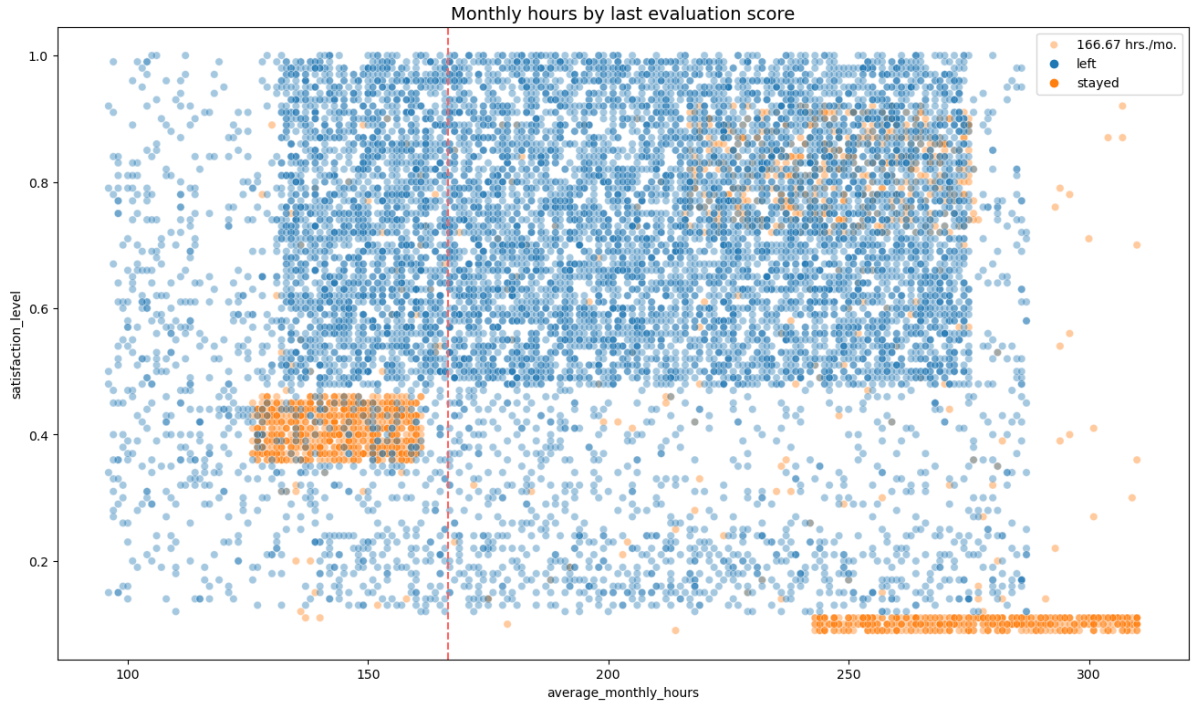
Out[14]:
```
left
1    145
Name: count, dtype: int64
```

This confirms that all employees with 7 projects did leave.

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

In [15]:

```
# Create a plot as needed
### YOUR CODE HERE ###

# Create scatterplot of `average_monthly_hours` versus `satisfaction_level`, compa
plt.figure(figsize=(16, 9))
sns.scatterplot(data=df1, x='average_monthly_hours', y='satisfaction_level', hue=
plt.axvline(x=166.67, color='#ff6361', label='166.67 hrs./mo.', ls='--')
plt.legend(labels=['166.67 hrs./mo.', 'left', 'stayed'])
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.

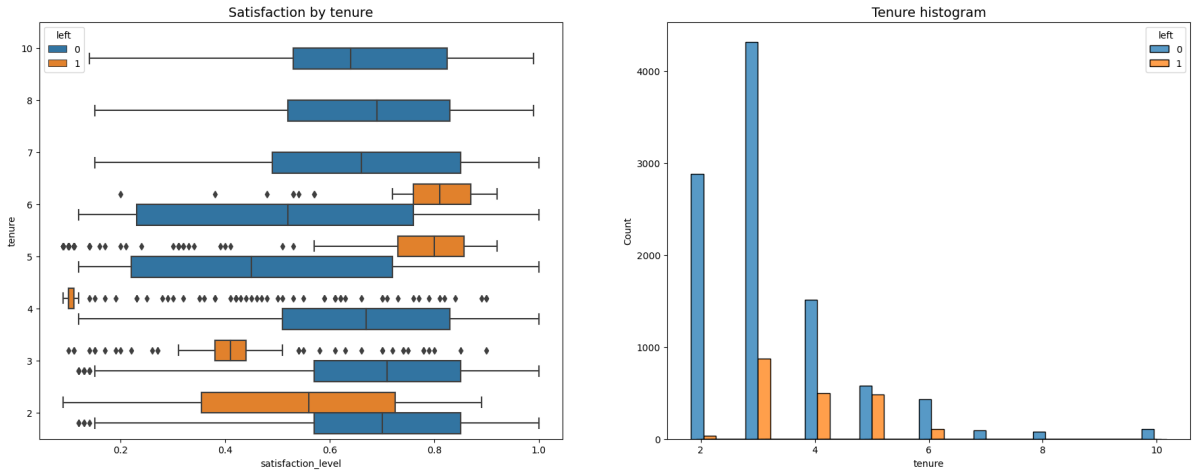
Finally, there is a group who worked ~210–280 hours per month, and they had satisfaction levels ranging ~0.7–0.9.

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.

In [16]:

```
# Create a plot as needed
### YOUR CODE HERE ###

# Set figure and axes
fig, ax = plt.subplots(1, 2, figsize = (22,8))

# Create boxplot showing distributions of `satisfaction_level` by tenure, compari
sns.boxplot(data=df1, x='satisfaction_level', y='tenure', hue='left', orient="h",
ax[0].invert_yaxis()
ax[0].set_title('Satisfaction by tenure', fontsize='14')

# Create histogram showing distribution of `tenure`, comparing employees who staye
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[
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.

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.

In [17]:
```
# Calculate mean and median satisfaction scores of employees who left and those wh
df1.groupby(['left'])['satisfaction_level'].agg([np.mean,np.median])
```

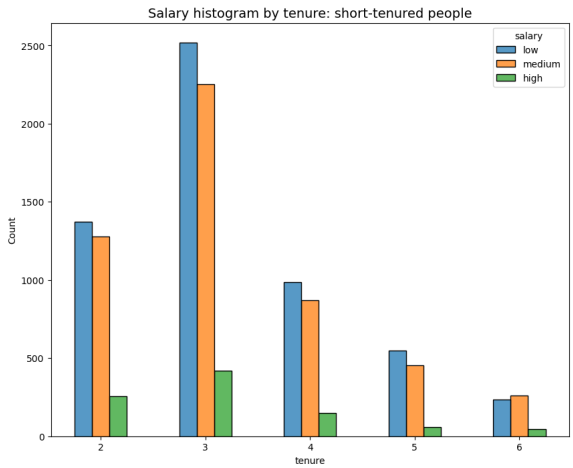
Out[17]:

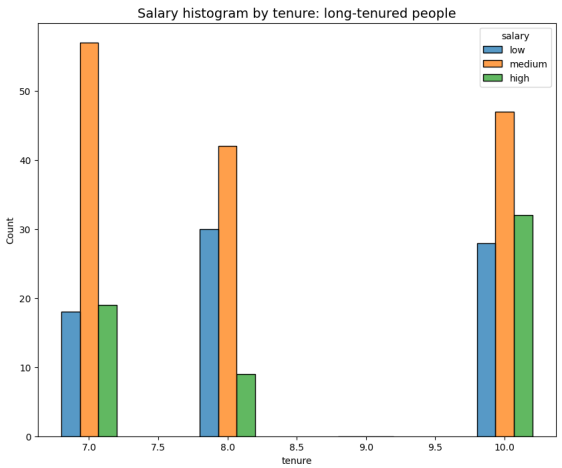
left	mean	median
0	0.667365	0.69
1	0.440271	0.41

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.

In [18]:
```
# Create a plot as needed
### YOUR CODE HERE ###

# 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].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].set_title('Salary histogram by tenure: long-tenured people', fontsize='14')
```



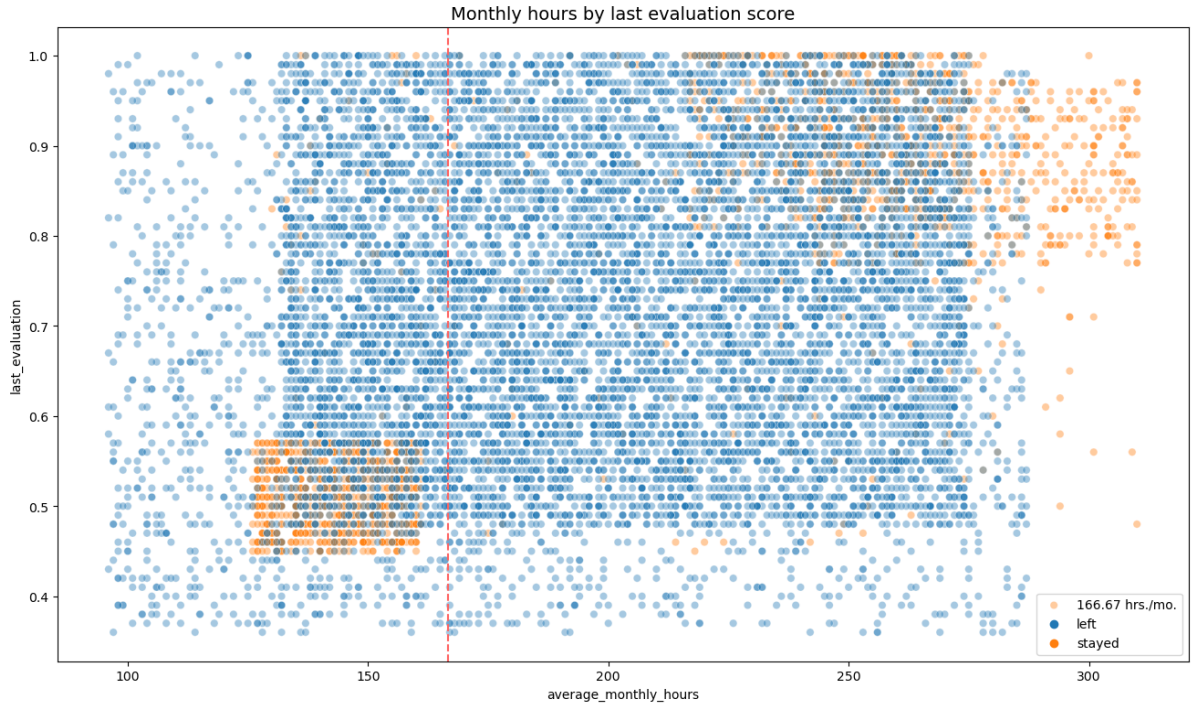


The plots above show that long-tenured employees were not disproportionately comprised of higher-paid employees.

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`.

In [19]:

```
# Create a plot as needed
### YOUR CODE HERE ###

# 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='le
plt.axvline(x=166.67, color='#ff6361', label='166.67 hrs./mo.', ls='--')
plt.legend(labels=['166.67 hrs./mo.', 'left', 'stayed'])
plt.title('Monthly hours by last evaluation score', fontsize='14');
```

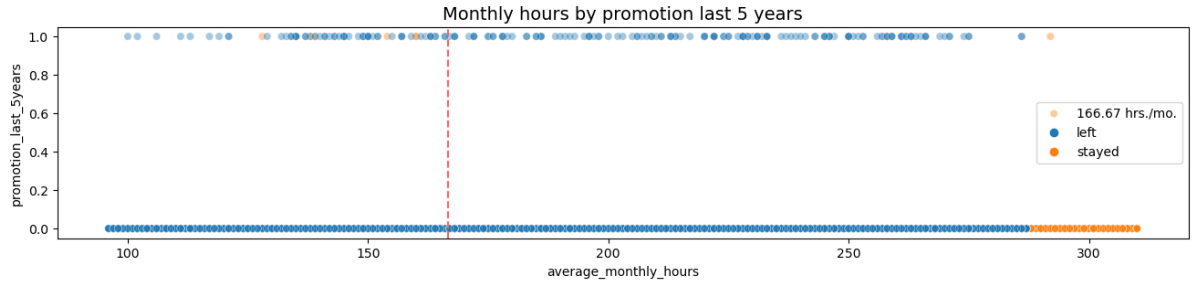


The following observations can be made from the scatterplot above:

- 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.

In [20]:
```
# Create a plot as needed
### YOUR CODE HERE ###

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



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

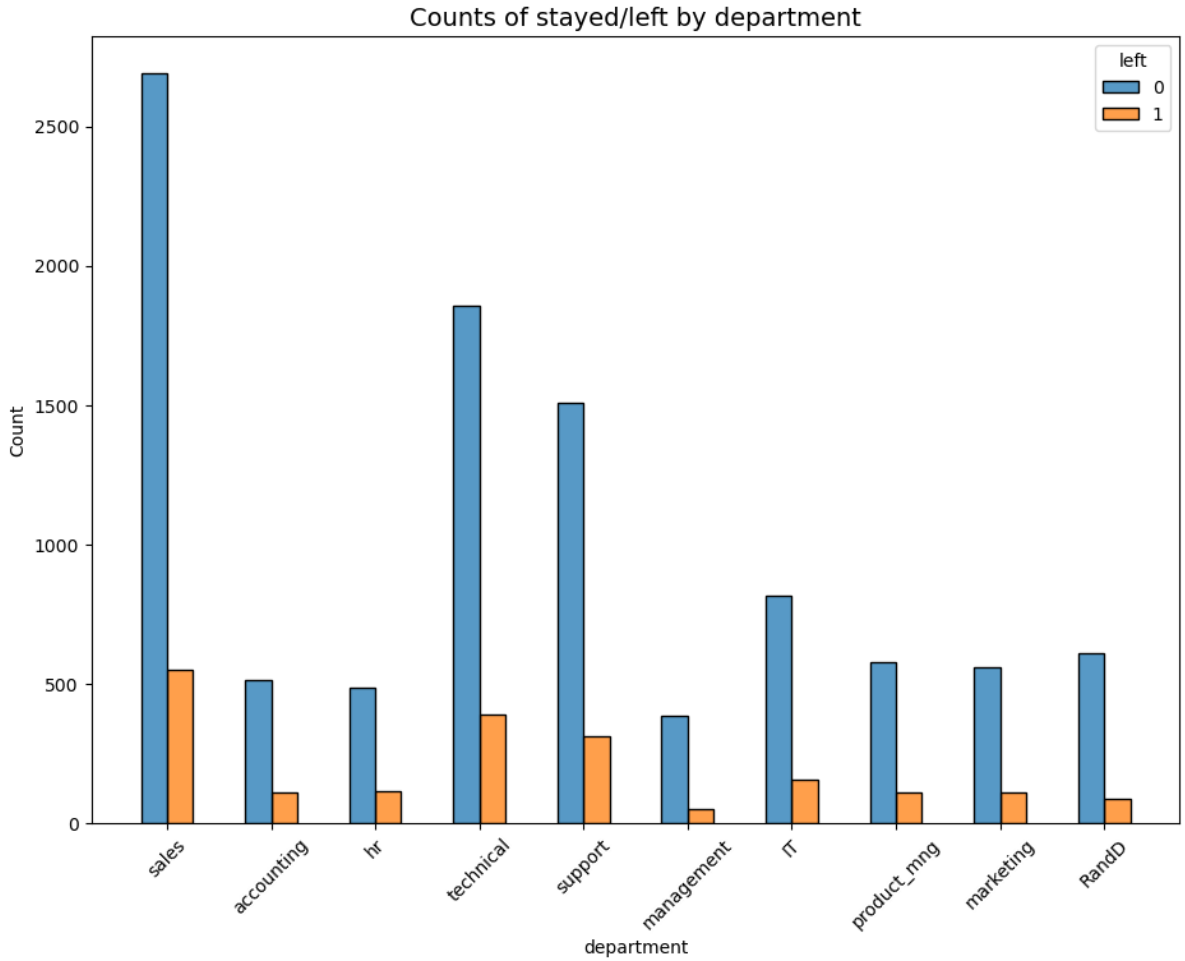
Next, you could inspect how the employees who left are distributed across departments.

In [21]:
```
# Display counts for each department
df1["department"].value_counts()
```

Out[21]:
```
department
sales          3239
technical      2244
support        1821
IT              976
RandD           694
product_mng     686
marketing       673
accounting      621
hr              601
management      436
Name: count, dtype: int64
```

In [22]:

```
# Create a plot as needed
### YOUR CODE HERE ###

# Create stacked histogram to compare department distribution of employees who le
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);

```

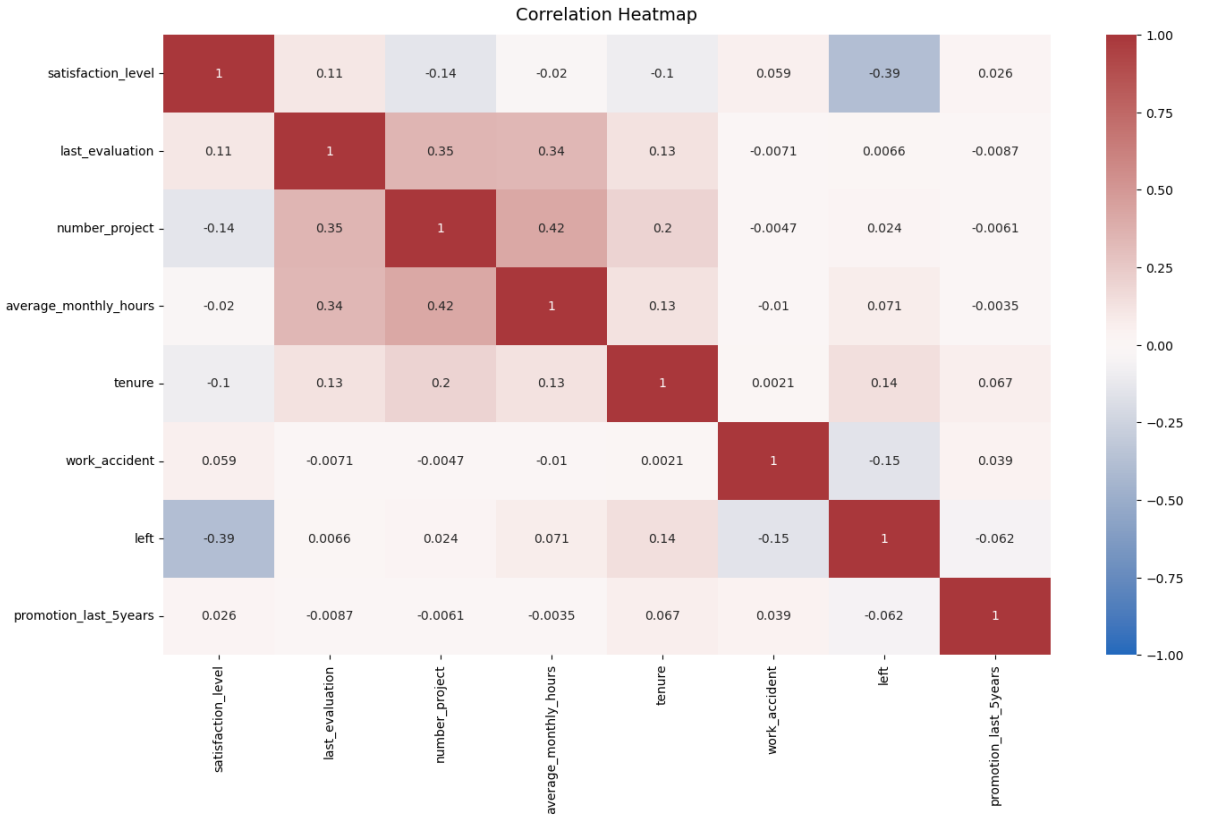


There doesn't seem to be any department that differs significantly in its proportion of employees who left to those who stayed.

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

In [24]:

```
# Create a plot as needed
### YOUR CODE HERE ###

# Plot a correlation heatmap
plt.figure(figsize=(16, 9))
heatmap = sns.heatmap(df0.corr(numeric_only=True), vmin=-1, vmax=1, annot=True, c
heatmap.set_title('Correlation Heatmap', fontdict={'fontsize':14}, pad=12);
```



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.

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.

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

🔎

Recall model assumptions

Logistic Regression model assumptions

- Outcome variable is categorical
- Observations are independent of each other
- No severe multicollinearity among X variables
- No extreme outliers
- Linear relationship between each X variable and the logit of the outcome variable
- Sufficiently large sample size

💭

Reflect on these questions as you complete the constructing stage.

- Do you notice anything odd?
- Which independent variables did you choose for the model and why?
- Are each of the assumptions met?
- How well does your model fit the data?
- Can you improve it? Is there anything you would change about the 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?

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

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).

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.

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.

Start by one-hot encoding the categorical variables as needed.

In [25]:
```
# One-hot encode the categorical variables as needed and save resulting dataframe
df_enc = pd.get_dummies(df1, prefix=['salary', 'dept'], columns = ['salary', 'dep
# Display the new dataframe
df_enc.head()
```

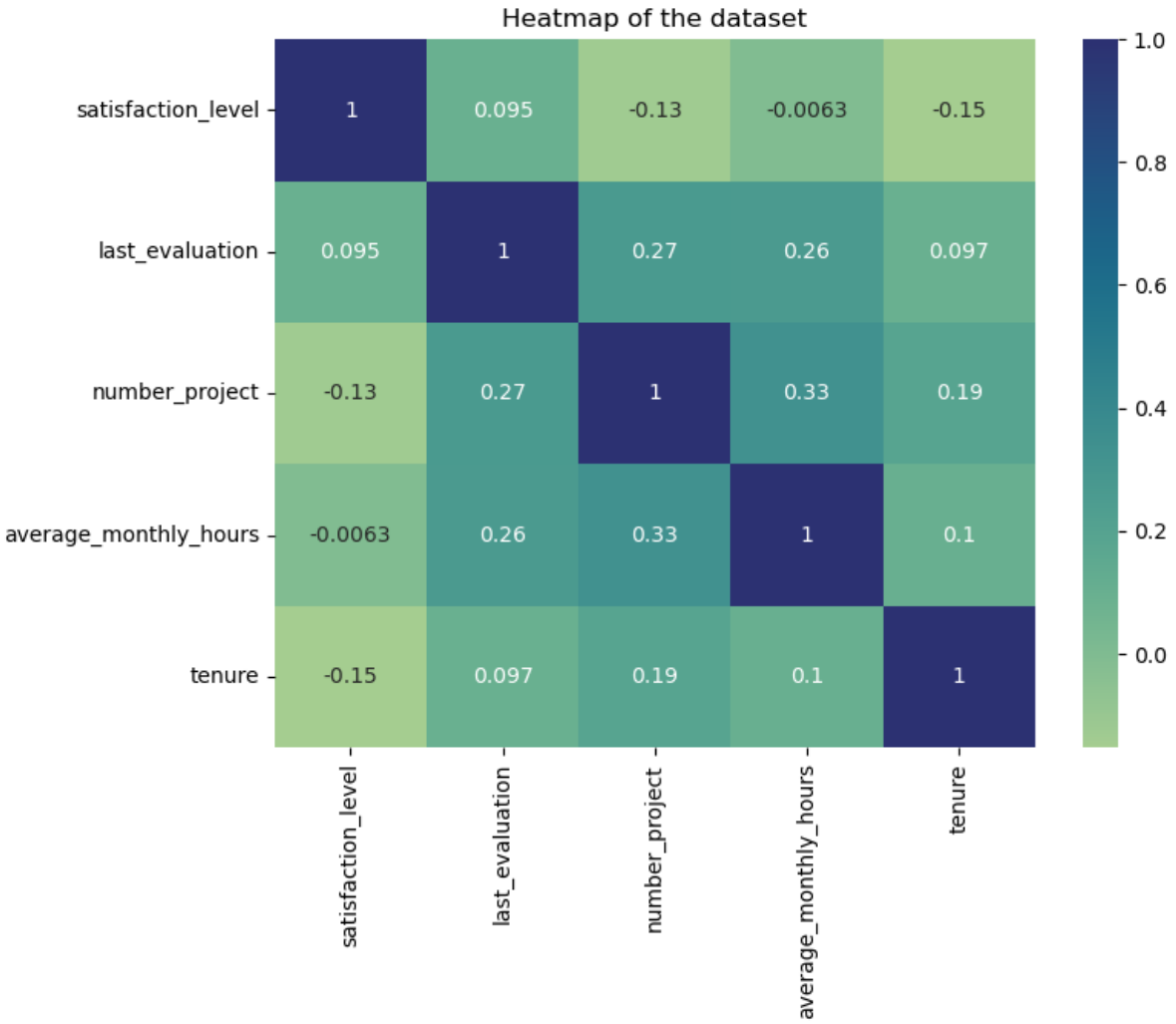
Out[25]:

	satisfaction_level	last_evaluation	number_project	average_monthly_hours	tenure	work_accident	left
0	0.38	0.53	2	157	3	0	1
1	0.80	0.86	5	262	6	0	1
2	0.11	0.88	7	272	4	0	1
3	0.72	0.87	5	223	5	0	1
4	0.37	0.52	2	159	3	0	1

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

In [26]:

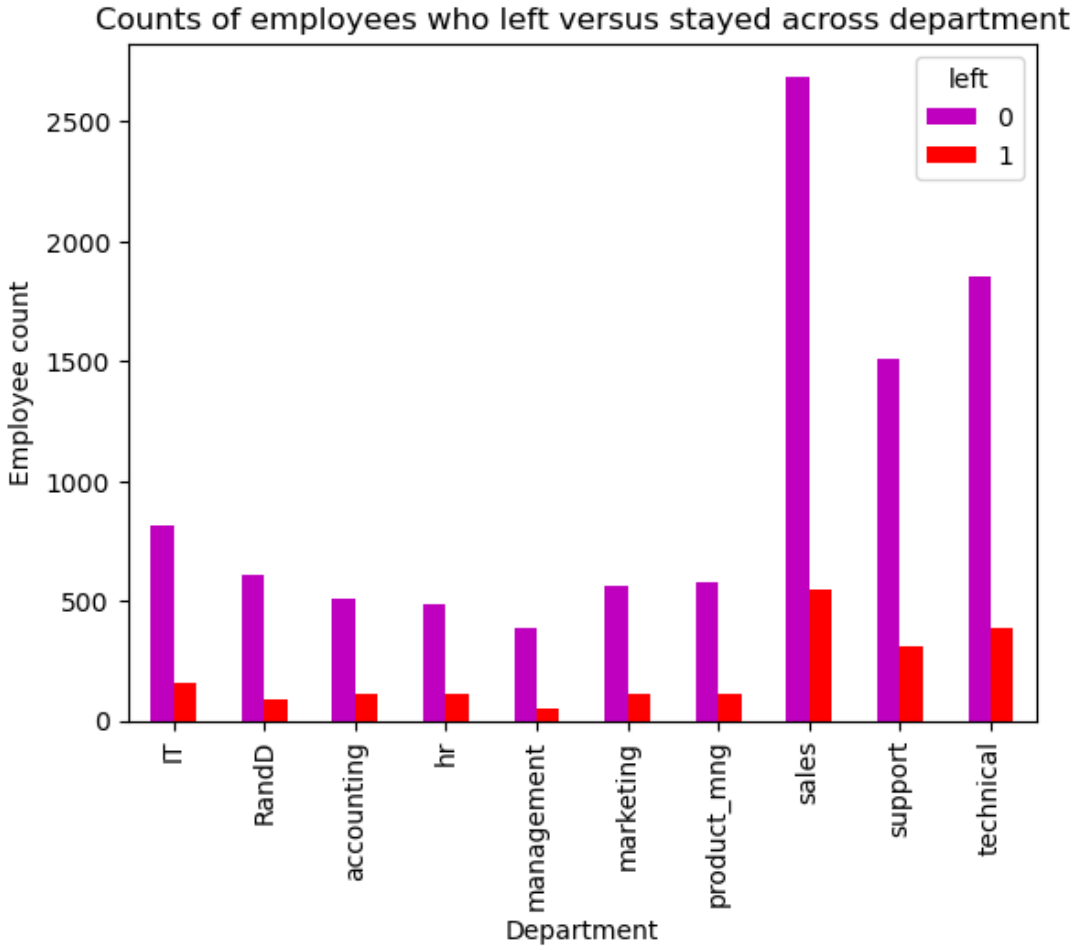
```
# Create a heatmap to visualize how correlated variables are
plt.figure(figsize=(8, 6))
sns.heatmap(df_enc[['satisfaction_level', 'last_evaluation', 'number_project', 'a
plt.title('Heatmap of the dataset')
plt.show()
```



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

In [27]:

```
# Create a stacked bart plot to visualize number of employees across department,
# In the legend, 0 (purple color) represents employees who did not leave, 1 (red
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()
```



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.

In [28]:
```
# Select rows without outliers in `tenure` and save resulting dataframe in a new v
df_logreg = df_enc[(df_enc['tenure'] >= lower_limit) & (df_enc['tenure'] <= upper_

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

Out[28]:

	satisfaction_level	last_evaluation	number_project	average_monthly_hours	tenure	work_accident	left
0	0.38	0.53	2	157	3	0	1
2	0.11	0.88	7	272	4	0	1
3	0.72	0.87	5	223	5	0	1
4	0.37	0.52	2	159	3	0	1
5	0.41	0.50	2	153	3	0	1

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

In [29]:
```
# Isolate the outcome variable
y = df_logreg['left']

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

Out[29]:
```
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` .

In [30]:
```
# Select the features you want to use in your model
X = df_logreg[['satisfaction_level', 'last_evaluation', 'number_project', 'averag

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

Out[30]:

	satisfaction_level	last_evaluation	number_project	average_monthly_hours	tenure	work_accident	prom
0	0.38	0.53	2	157	3	0	
2	0.11	0.88	7	272	4	0	
3	0.72	0.87	5	223	5	0	
4	0.37	0.52	2	159	3	0	
5	0.41	0.50	2	153	3	0	

Split the data into training set and testing set.

In [31]:
```
# Split the data into training set and testing set
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_s
```

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

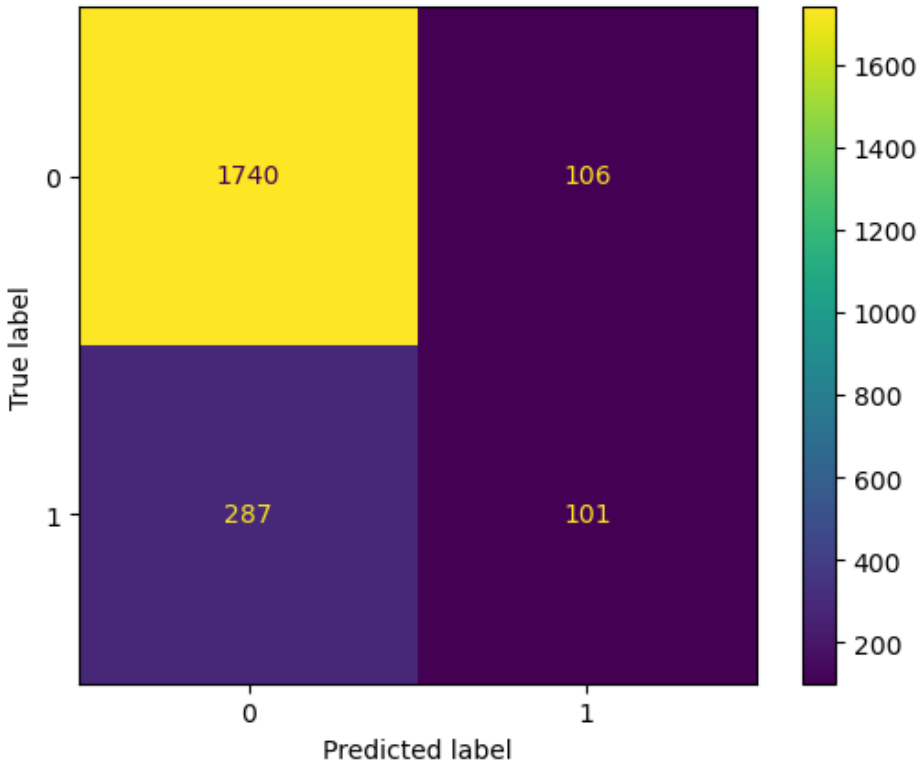
In [32]:
```
# Construct a logistic regression model and fit it to the training dataset
log_clf = LogisticRegression(random_state=42, max_iter=500).fit(X_train, y_train)
```

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

In [33]:
```
# 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.

In [34]:
```
# 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

# Plot confusion matrix
log_disp.plot()

# 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.

In [35]:
```
df_logreg['left'].value_counts(normalize=True)
```

Out[35]:
```
left
0    0.831468
1    0.168532
Name: proportion, 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.

In [36]:
```
# 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      0.94      0.90      1846
    Predicted would leave       0.49      0.26      0.34       388

                 accuracy                           0.82      2234
                macro avg       0.67      0.60      0.62      2234
             weighted avg       0.79      0.82      0.80      2234
```

The classification report above shows that the logistic regression model achieved a precision of 80%, recall of 83%, f1-score of 80% (all weighted averages), and accuracy of 83%.

Modeling Approach B: Tree-based Model

This approach covers implementation of Decision Tree and Random Forest.

Encode the categorical variables.

In [37]:
```
# Encode categorical variables
df2 = pd.get_dummies(df1)
```

Isolate the outcome variable.

In [38]:
```
# Isolate the outcome variable
y = df2['left']

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

Out[38]:
```
0    1
1    1
2    1
3    1
4    1
Name: left, dtype: int64
```

Select the features.

In [39]:
```
# Select the features
X = df2.drop('left', axis=1)

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

Out[39]:

	satisfaction_level	last_evaluation	number_project	average_monthly_hours	tenure	work_accident	prom
0	0.38	0.53	2	157	3	0	
1	0.80	0.86	5	262	6	0	
2	0.11	0.88	7	272	4	0	
3	0.72	0.87	5	223	5	0	
4	0.37	0.52	2	159	3	0	

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

In [40]:
```
# Create test data
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, stratify=
# Create train & validate data
X_tr, X_val, y_tr, y_val = train_test_split(X_train, y_train, test_size=0.25, str
```

Decision tree - Round 1

Construct a decision tree model and set up cross-validated grid-search to exhaustively search for the best model parameters.

In [41]:
```
# 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.

In [42]:
```
%%time
tree1.fit(X_tr, y_tr)
```

```
Wall time: 10.1 s
```

Out[42]:
```
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={'f1', 'roc_auc', 'accuracy', 'precision', 'recall'})
```

Identify the optimal values for the decision tree parameters.

In [43]:
```
# Check best parameters
tree1.best_params_
```

Out[43]:
```
{'max_depth': 4, 'min_samples_leaf': 1, 'min_samples_split': 2}
```

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

In [44]:
```
# Check best AUC score on CV
tree1.best_score_
```

Out[44]:
```
0.9703634179699269
```

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.

In [57]:

```
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 ta
        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 GridSearch
    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]].idxma

    # 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 = {'Model': model_name,
                         'AUC': auc,
                         'Precision': precision,
                         'Recall': recall,
                         'F1': f1,
                         'Accuracy': accuracy,
                         }
    table = pd.DataFrame(table, index=range(1))

    return table
```

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

In [58]:

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

Out[58]:

	Model	AUC	Precision	Recall	F1	Accuracy
0	decision tree cv	0.970363	0.922167	0.921337	0.921719	0.974007

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

Random forest - Round 1

Construct a random forest model and set up cross-validated grid-search to exhuastively search for the best model parameters.

In [59]:
```
# 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, 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.

In [60]:
```
%%time
rf1.fit(X_tr, y_tr) # --> Wall time: ~22min
```

```
Wall time: 26min 1s
```

Out[60]:
```
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, 500]},
             refit='roc_auc',
             scoring={'f1', 'roc_auc', 'accuracy', 'precision', 'recall'})
```

Specify path to where you want to save your model.

In [62]:
```
# Define a path to the folder where you want to save the model
path = 'C:\\Users\\USER\\Google Advanced Data Analytics Certificate\\Capstone Cou
```

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

In [63]:
```
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)
```

In [64]:
```
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.

In [65]:
```
# Write pickle
write_pickle(path, rf1, 'hr_rf1')
```

In [66]:
```
# Read pickle
rf1 = read_pickle(path, 'hr_rf1')
```

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

In [67]:
```
# Check best AUC score on CV
rf1.best_score_
```

Out[67]:
```
0.9795790967836983
```

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

In [68]:
```
# Check best params
rf1.best_params_
```

Out[68]:
```
{'max_depth': 5,
 'max_features': 1.0,
 'max_samples': 0.7,
 'min_samples_leaf': 1,
 'min_samples_split': 3,
 'n_estimators': 500}
```

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

In [69]:
```
# Get all CV scores
rf1_cv_results = make_results('random forest cv', rf1, 'auc')
print(tree1_cv_results)
print(rf1_cv_results)
```

```
              Model       AUC  Precision    Recall        F1  Accuracy
0  decision tree cv  0.970363   0.922167  0.921337  0.921719  0.974007
              Model       AUC  Precision    Recall        F1  Accuracy
0  random forest cv  0.979579   0.943576  0.923021  0.933145  0.978037
```

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 0.008 lower, which is a negligible amount). This indicates that the random forest model mostly outperforms the decision tree model.

Next, you can evaluate these models on the validation set.

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

In [70]:
```
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 ta
        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 mod
    '''

    preds = model.best_estimator_.predict(X_test_data)

    auc = round(roc_auc_score(y_test_data, preds), 3)
    accuracy = round(accuracy_score(y_test_data, preds), 3)
    precision = round(precision_score(y_test_data, preds), 3)
    recall = round(recall_score(y_test_data, preds), 3)
    f1 = round(f1_score(y_test_data, preds), 3)

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

    return table
```

Apply the function defined above to get scores for the decision tree model and the random forest model.

In [71]:
```
# Get the results on validation set for both models
tree1_val_results = get_scores('decision tree1 val', tree1, X_val, y_val)
rf1_val_results = get_scores('random forest1 val', rf1, X_val, y_val)

# Concatenate validation scores into table
all_val_results1 = [tree1_val_results, rf1_val_results]
all_val_results1 = pd.concat(all_val_results1).sort_values(by='AUC', ascending=Fa
all_val_results1
```

Out[71]:

	model	AUC	precision	recall	f1	accuracy
0	random forest1 val	0.954	0.955	0.917	0.936	0.979
0	decision tree1 val	0.952	0.924	0.920	0.922	0.974

On the validation set, the random forest model outperforms the decision tree model across most metrics.

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

In [72]:
```
# Get predictions on test data
rf1_test_scores = get_scores('random forest1 test', rf1, X_test, y_test)
rf1_test_scores
```

Out[72]:

	model	AUC	precision	recall	f1	accuracy
0	random forest1 test	0.955	0.961	0.917	0.938	0.98

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 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.

In [73]:
```
# Drop `satisfaction_level` and save resulting dataframe in new variable
df3 = df1.drop('satisfaction_level', axis=1)

# Display first few rows of new dataframe
df3.head()
```

Out[73]:

	last_evaluation	number_project	average_monthly_hours	tenure	work_accident	left	promotion_last_5y
0	0.53	2	157	3	0	1	
1	0.86	5	262	6	0	1	
2	0.88	7	272	4	0	1	
3	0.87	5	223	5	0	1	
4	0.52	2	159	3	0	1	

In [74]:
```
# Create `overworked` column. For now, it's identical to average monthly hours.
df3['overworked'] = df3['average_monthly_hours']

# Inspect max and min average monthly hours values
print('Max hours:', df3['overworked'].max())
print('Min hours:', df3['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`

In [75]:
```
# Define `overworked` as working > 175 hrs/week
df3['overworked'] = (df3['overworked'] > 175).astype(int)

# Display first few rows of new column
df3['overworked'].head()
```

Out[75]:
```
0    0
1    1
2    1
3    1
4    0
Name: overworked, dtype: int32
```

Drop the `average_monthly_hours` column.

In [76]:
```
# Drop the `average_monthly_hours` column
df3 = df3.drop('average_monthly_hours', axis=1)

# Display first few rows of resulting dataframe
df3.head()
```

Out[76]:

	last_evaluation	number_project	tenure	work_accident	left	promotion_last_5years	department	salary
0	0.53	2	3	0	1	0	sales	low
1	0.86	5	6	0	1	0	sales	medium
2	0.88	7	4	0	1	0	sales	medium
3	0.87	5	5	0	1	0	sales	low
4	0.52	2	3	0	1	0	sales	low

Start by one-hot encoding the categorical variables as needed.

In [77]:
```
# One-hot encode the categorical variables as needed and save resulting dataframe
df4 = pd.get_dummies(df3)

# Display the new dataframe
df4.head()
```

Out[77]:

	last_evaluation	number_project	tenure	work_accident	left	promotion_last_5years	overworked	depart
0	0.53	2	3	0	1	0	0	
1	0.86	5	6	0	1	0	1	
2	0.88	7	4	0	1	0	1	
3	0.87	5	5	0	1	0	1	
4	0.52	2	3	0	1	0	0	

Isolate the outcome variable.

In [78]:
```
# Isolate the outcome variable
y = df4['left']

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

Out[78]:
```
0    1
1    1
2    1
3    1
4    1
Name: left, dtype: int64
```

Select the features.

In [79]:
```
# Select the features
X = df4.drop('left', axis=1)

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

Out[79]:

	last_evaluation	number_project	tenure	work_accident	promotion_last_5years	overworked	department
0	0.53	2	3	0	0	0	Fa
1	0.86	5	6	0	0	1	Fa
2	0.88	7	4	0	0	1	Fa
3	0.87	5	5	0	0	1	Fa
4	0.52	2	3	0	0	0	Fa

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

In [80]:
```
# Create test data
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, stratify=

# Create train & validate data
X_tr, X_val, y_tr, y_val = train_test_split(X_train, y_train, test_size=0.25, str
```

Decision tree - Round 2

In [81]:
```
# 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')
```

In [82]:
```
%%time
tree2.fit(X_tr, y_tr)
```

```
Wall time: 3.51 s
```

Out[82]:
```
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={'f1', 'roc_auc', 'accuracy', 'precision', 'recall'})
```

In [83]:
```
# Check best params
tree2.best_params_
```

Out[83]:
```
{'max_depth': 6, 'min_samples_leaf': 1, 'min_samples_split': 4}
```

In [84]:
```
# Check best AUC score on CV
tree2.best_score_
```

Out[84]:
```
0.9534827790328492
```

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

Next, check the other scores.

In [85]:
```
# Get all CV scores
tree2_cv_results = make_results('decision tree2 cv', tree2, 'auc')
tree2_cv_results
```

Out[85]:

	Model	AUC	Precision	Recall	F1	Accuracy
0	decision tree2 cv	0.953483	0.864826	0.902098	0.883024	0.960245

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

In [86]:
```
# 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, 500],
             }

# 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')
```

In [87]:
```
%%time
rf2.fit(X_tr, y_tr) # --> Wall time: 17min 5s
```

```
Wall time: 20min 10s
```

Out[87]:
```
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, 500]},
             refit='roc_auc',
             scoring={'f1', 'roc_auc', 'accuracy', 'precision', 'recall'})
```

In [88]:
```
# Write pickle
write_pickle(path, rf2, 'hr_rf2')
```

In [89]:
```
# Read in pickle
rf2 = read_pickle(path, 'hr_rf2')
```

In [90]:
```
# Check best params
rf2.best_params_
```

Out[90]:
```
{'max_depth': None,
 'max_features': 1.0,
 'max_samples': 0.7,
 'min_samples_leaf': 3,
 'min_samples_split': 2,
 'n_estimators': 300}
```

In [91]:
```
# Check best AUC score on CV
rf2.best_score_
```

Out[91]:
```
0.9656664586139387
```

In [92]:
```
# Get all CV scores
rf2_cv_results = make_results('random forest2 cv', rf2, 'auc')
print(tree2_cv_results)
print(rf2_cv_results)
```

```
                Model       AUC  Precision    Recall        F1  Accuracy
0  decision tree2 cv  0.953483   0.864826  0.902098  0.883024  0.960245
                Model       AUC  Precision    Recall        F1  Accuracy
0  random forest2 cv  0.965666   0.909473  0.879506  0.894049  0.965388
```

Again, the scores dropped slightly, but the random forest performs better than the decision tree.

Test the models on the validation set now.

In [93]:
```
# Collect validation scores
tree2_val_results = get_scores('decision tree2 val', tree2, X_val, y_val)
rf2_val_results = get_scores('random forest2 val', rf2, X_val, y_val)

# Concatenate validation scores into table
all_val_results2 = [tree2_val_results, rf2_val_results]
all_val_results2 = pd.concat(all_val_results2).sort_values(by='AUC', ascending=Fa
all_val_results2
```

Out[93]:

	model	AUC	precision	recall	f1	accuracy
0	decision tree2 val	0.942	0.883	0.907	0.895	0.965
0	random forest2 val	0.933	0.905	0.884	0.895	0.965

It appears that the random forest performs slightly better than the decision tree, across most of the evaluation metrics.

Use this random forest model to predict on the test set now.

In [94]:
```
# Get predictions on test data
rf2_test_scores = get_scores('random forest2 test', rf2, X_test, y_test)
rf2_test_scores
```

Out[94]:

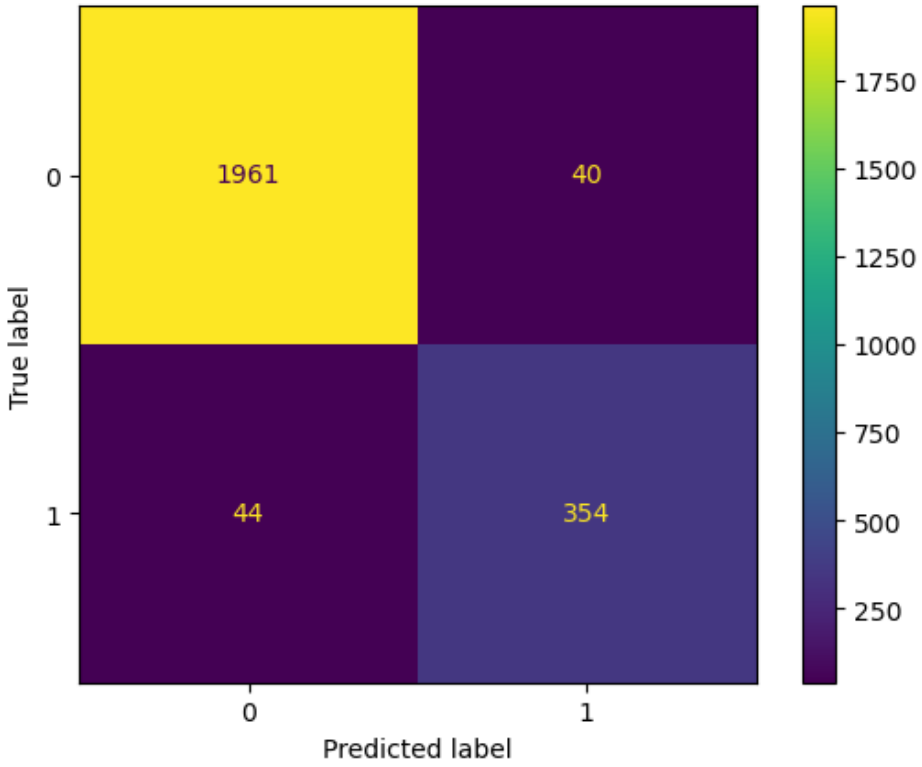
	model	AUC	precision	recall	f1	accuracy
0	random forest2 test	0.935	0.898	0.889	0.894	0.965

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

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

In [95]:

```
# 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();
```

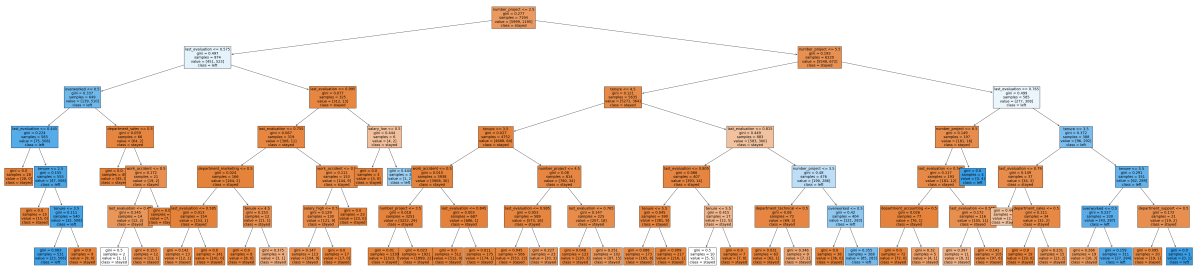


The model predicts more false positives than false negatives, which means that some employees may be identified as at risk of quitting or getting fired, when that's actually not the case. who are not actually at risk of doing so. But this is still a strong model.

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 splits

In [96]:
```
# Plot the tree
plt.figure(figsize=(85,20))
plot_tree(tree2.best_estimator_, max_depth=6, fontsize=14, feature_names=X.columns
          class_names={0:'stayed', 1:'left'}, filled=True);
plt.show()
```



Decision tree feature importance

You can also get feature importance from decision trees (see the DecisionTreeClassifier scikit-learn documentation (https://scikit-learn.org/stable/modules/generated/sklearn.tree.DecisionTreeClassifier.html#sklearn.tree.DecisionTreeClassifie for details).

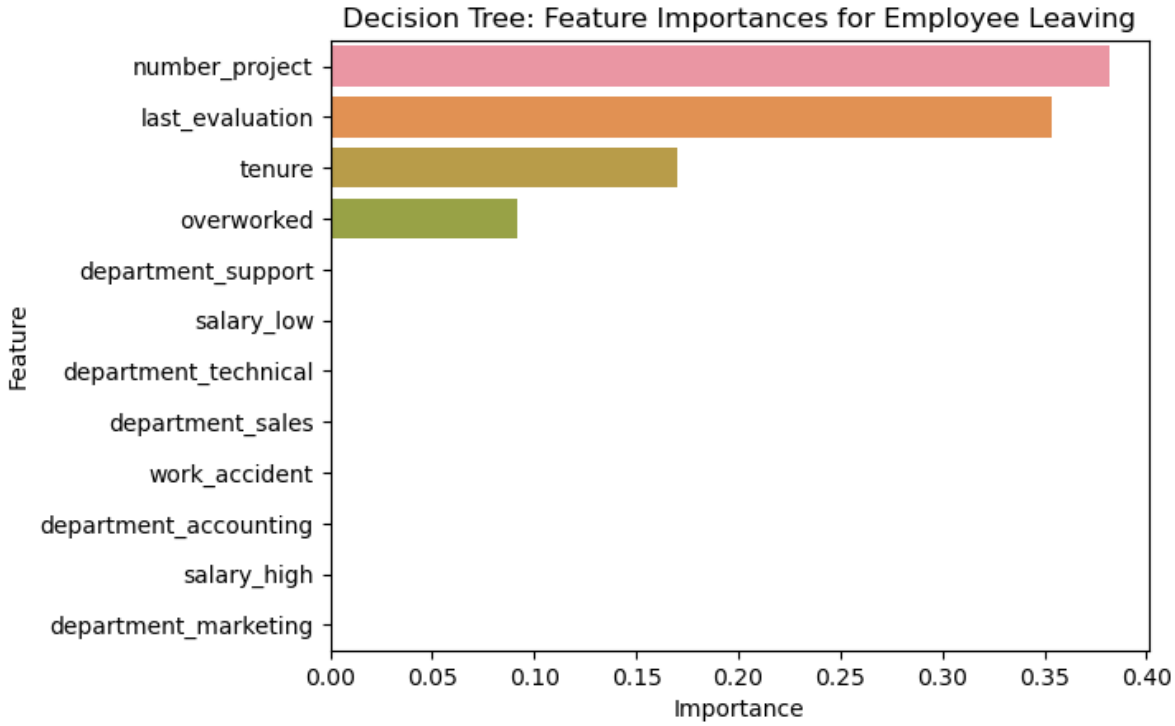
In [97]:
```
#tree2_importances = pd.DataFrame(tree2.best_estimator_.feature_importances_, colu
tree2_importances = pd.DataFrame(tree2.best_estimator_.feature_importances_, colu
tree2_importances = tree2_importances.sort_values(by='gini_importance', ascending

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

Out[97]:

	gini_importance
number_project	0.381767
last_evaluation	0.353482
tenure	0.169771
overworked	0.091517
department_support	0.001099
salary_low	0.000853
department_technical	0.000429
department_sales	0.000357
work_accident	0.000282
department_accounting	0.000239
salary_high	0.000120
department_marketing	0.000084

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

In [98]:
```
sns.barplot(data=tree2_importances, x="gini_importance", y=tree2_importances.inde
plt.title("Decision Tree: Feature Importances for Employee Leaving", fontsize=12)
plt.ylabel("Feature")
plt.xlabel("Importance")
plt.show()
```




```
# This is formatted as code
```

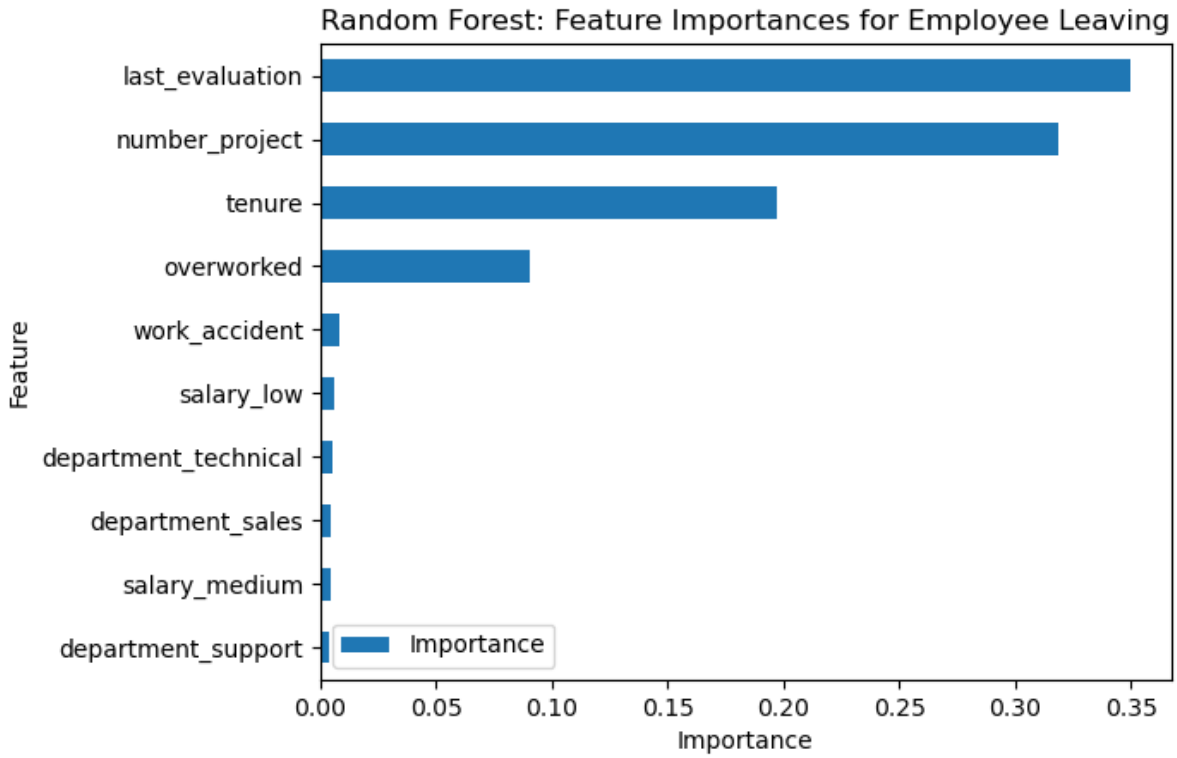
The barplot above shows that in this decision tree model, `last_evaluation`, `number_project`, `tenure`, and `overworked` have the highest importance, in that order. These variables are most helpful in predicting the outcome variable, `left`.

Random forest feature importance

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

In [99]:

```
# 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
ax1.set_ylabel("Feature")
ax1.set_xlabel("Importance")

plt.show()
```



The plot above shows that in this random forest model, `last_evaluation`, `number_project`, `tenure`, `overworked`, `work_accident`, and `salary_low` have the highest importance, in that order. These variables are most helpful in predicting the outcome variable, `left`.

pacE: Execute Stage

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

Recall 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.

Reflect on these questions as you complete the executing stage.

- What key insights emerged from your model(s)?
- What business recommendations do you propose based on the models built?
- What potential recommendations would you make to your manager/company?
- Do you think your model could be improved? Why or why not? How?
- What business recommendations do you propose based on the models built?
- Given what you know about the data and the models you were using, what other questions could you address for the team?
- 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?

Step 4. Results and Evaluation

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

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

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.

Next Steps

It may be justified to still have some concern about data leakage. It could be prudent to consider how predictions change when `last_evaluation` is removed from the data. It's possible that evaluations aren't performed very frequently, in which case it would be useful to be able to predict employee retention without this feature. It's also possible that the evaluation score determines whether an employee leaves or stays, in which case it could be useful to pivot and try to predict performance score. The same could be said for satisfaction score.

For another project, you could try building a K-means model on this data and analyzing the clusters. This may yield valuable insight.

In [ ]:

```
1
```