

Overview

In this practical, we were to use Python to create a Jupyter Notebook to analyse a large amount of data in the form of a csv file (census2011.csv). Using pandas and matplotlib, we had to check that the data was consistent, creating a new file of refined data if it wasn't, display some data analysis (number of records, number of records per variable, types of variables, etc.), and build bar charts and pie charts of given variables. The extensions were also all implemented by us, except the last hard one, which was to use virtualisation tools to provide an environment to run our programme. The rest, which we implemented, were: to build tables based on 2 variables (easy), to build 3d plots based on these tables (medium), to perform queries using pandas (easy - e.g. placing a restriction on the value for Economic Activity), to use ipywidgets to display number of records for the selected values of two variables (medium), to create a map which displays the regions, which the user could select to display a pie chart for, based on a given variable (hard) and to try different data sets from other websites, with at least 10,000 records (hard).

The implementations and further decision explanations can be found below in the following cells. In general, a cell contains 1 or more function implementations, and is followed by one or more cells using these functions.

This cell contains all the functions used to go through a csv file using pandas, and check whether its data is consistent. If it isn't, a "refined_data.csv" file is created with the refined data. A data array variable is used to hold the information of a given csv (which can be changed for other data files), where each item of the list is a tuple, where the first variable contains the variable name, and the second is a list containing its possible values.

- `check_consistency_col`:

this function takes in two arrays, and returns false if the first array contains an item that isn't in the second array. It is used to check that a list is legal (the 2nd array contains the legal items)

- `check`:

this function takes in an array of possible legal values, and using the above function, it checks all of the items in the csv file against this array.

- `check_val`:

this is a similar function to `check_consistency_col`, except it checks that a single value is legal rather than an array. It is used when re-writing the data to refine it, as each value needs to be checked.

- `check_file`:

this function checks the whole file, by using the `check` function, and passing the data array as a parameter.

In this way, only by changing the initial file and a data array, any big csv file can be checked. If `check` fails, we go through the data value by value, adding it onto a row only if all the values in the given row are legal (which can sometimes take a while as each value needs to be checked). The row is then written on to the new file. To check the ID field, the function simply checks that it is unique, accepting any value as an ID, as different files may use different approaches to IDs. When using these functions with other files, the legal data array for the ID field should be left empty, otherwise it will be treated as another field.

In [4]:

```
import pandas as pd

refined_file = open("../data/refined_data.csv", "w+")
FILENAME = "../data/census2011.csv"
DATA_ARRAY = [('Person ID', []),
               ('Region', ["E12000001", "E12000002", "E12000003",
                           "E12000004", "E12000005", "E12000006",
                           "E12000007", "E12000008", "E12000009", "W92000004"]),
               ('Residence Type', ["C", "H"]),
               ('Family Composition', [-9, 1, 2, 3, 4, 5, 6]),
```

```
(('Population Base', list(range(1, 4))),
('Sex', [1, 2]),
('Age', list(range(1, 9))),
('Marital Status', list(range(1, 6))),
('Student', [1, 2]),
('Country of Birth', [-9, 1, 2]),
('Health', [-9] + list(range(1, 6))),
('Ethnic Group', [-9] + list(range(1, 6))),
('Religion', [-9] + list(range(1, 10))),
('Economic Activity', [-9] + list(range(1, 10))),
('Occupation', [-9] + list(range(1, 10))),
('Industry', [-9] + list(range(1, 13))),
('Hours worked per week', [-9] + list(range(1, 5))),
('Approximated Social Grade', [-9] + list(range(1, 5))))]
```

```
TEXT_ARRAY = [('Person ID', []),
('Region', ["North East", "North West", "Yorkshire and the Humber", "East Midlands",
"West Midlands", "East of England", "London", "South East",
"South West",
"Wales"])),
('Residence Type', ["Resident in a communal establishment",
"Not resident in a communal establishment"]),
('Family Composition', ["Not in a family",
"Married/same-sex civil partnership couple",
"Cohabiting couple",
"Lone parent family (male head)",
"Lone parent family (female head)",
"Other",
"No code required"]),
('Population Base', ["Usual resident",
"Student living away from home",
"Short-term resident"]),
('Sex', ["Male", "Female"]),
('Age', ["0 to 15",
"16 to 24",
"25 to 34",
"35 to 44",
"45 to 54",
"55 to 64",
"65 to 74",
"75 and over"]),
('Marital Status', ["Single",
"Married or in a registered same-sex civil partnership",
"Separated but still legally married",
"Divorced or formerly in a same-sex civil partnership",
"Widowed or surviving partner"]),
('Student', ["Student", "Not a student"]),
('Country of Birth', ["UK", "Non UK", "No Code required"]),
('Health', ["Very good health",
"Good health",
"Fair health",
"Bad health",
"Very bad health",
"No code required"]),
('Ethnic Group', ["White",
"Mixed",
"Asian and Asian British",
"Black or Black British",
```

```

        "Chinese or Other ethnic group",
        "No code required"])),
('Religion', ["No religion",
               "Christian",
               "Buddhist",
               "Hindu",
               "Jewish",
               "Muslim",
               "Sikh",
               "Other",
               "Not stated",
               "No code required"]),
('Economic Activity', ["Employed",
                       "Self-employed",
                       "Unemployed",
                       "Full-time student",
                       "Retired",
                       "Student",
                       "Looking after home or family",
                       "Long-term sick or disabled",
                       "Other",
                       "No code required"]),
('Occupation', ["Managers, Directors and Senior Officials",
                 "Professional Occupations",
                 "Associate Professional and Technical Occupations",
                 "Administrative and Secretarial Occupations",
                 "Skilled Trades Occupations",
                 "Caring, Leisure and Other Service Occupations",
                 "Sales and Customer Service Occupations",
                 "Process, Plant and Machine Operatives",
                 "Elementary Occupations",
                 "No code required"]),
('Industry', ["Agriculture, forestry and fishing",
               "Mining and quarrying; Manufacturing; Electricity, gas, "
               "steam and air conditioning system; Water supply",
               "Construction", "Wholesale and retail trade; Repair of m
otor vehicles and motorcycles",
               "Accommodation and food service activities",
               "Transport and storage; Information and communication",
               "Financial and insurance activities; Intermediation",
               "Real estate activities; Professional, scientific and te
chnical activities; Administrative and "
               "support service activities",
               "Public administration and defence; compulsory social se
curity",
               "Education",
               "Human health and social work activities",
               "Other community, social and personal service activitie
s; Private households employing domestic staff; "
               "Extra-territorial organisations and bodies",
               "No code required"]),
('Hours worked per week', ["Part-time: 15 or less hours worked",
                           "Part-time: 16 to 30 hours worked",
                           "Full-time: 31 to 48 hours worked",
                           "Full-time: 49 or more hours worked",
                           "No code required"]),
('Approximated Social Grade', ["AB", "C1", "C2", "DE", "No code requir
ed"])]

```

```

def check_consistency_col(array_of_values, array_of_legal_values):
    if not type(array_of_legal_values) == list:
        print(str(type(array_of_values)) + " " + str(type(array_of_legal_values)))
        print("Invalid arguments for check_consistency_col. Arguments need to be lists of values. ")
    return
    for item in array_of_values:
        if item not in array_of_legal_values:
            return False
    return True

def check(array_of_values):
    for (x, y) in array_of_values:
        if not type(x) == str or not type(y) == list:
            print("Invalid arguments for check. Arguments need to be an array of tuples, where each tuple "
                  "contains a String followed by a list of legal values for the row with the given String.")
        return
    if y:
        if not check_consistency_col(df[x].unique(), y):
            return False
    return True

def check_val(value, array_of_values):
    if not type(array_of_values) == list:
        print("Invalid arguments for check_val. Second argument needs to be a list of values to compare with the "
              "first value.")
    return
    if value not in array_of_values:
        return False
    return True

def check_file(array_of_values):
    if not type(array_of_values) == list:
        print("Invalid arguments for check_file. Arguments need to be an array of tuples, where each tuple "
              "contains a String followed by a list of legal values for the row with the given String.")
    return
    flag = True
    if not check(array_of_values):
        flag = False
    else:
        print("All records are legal - no new file needed \n\n")

    final_row = ""
    ID = []
    counter = 0

    if not flag:
        for (x, y) in array_of_values:
            if not type(x) == str or not type(y) == list:
                print("Invalid arguments for check_file. Arguments need to be an array of tuples, where each tuple "
                      "contains a String followed by a list of legal values for the row with the given String.")

```

```

        return
    if counter != 0:
        refined_file.write(',')
        refined_file.write(str(x))
        counter += 1
    refined_file.write('\n')
    for index, row in df.iterrows():
        flag = True
        for (x, y) in array_of_values:
            # check if array is empty (if so, we are dealing with ID)
            if not y:
                # check if the ID is unique
                if row[x] not in ID:
                    final_row += str(row[x]) + ','
                    ID += x
                else:
                    flag = False
                    break
            else:
                # check that current value in row is correct
                if not check_val(row[x], y):
                    flag = False
                    break
                else:
                    final_row += str(row[x]) + ','
        if flag:
            refined_file.write(final_row + '\n')
            final_row = ""
    print("New file created with refined data")

```

```

IOErrorTraceback (most recent call last)
<ipython-input-4-d31da52d58a1> in <module>()
      1 import pandas as pd
      2
----> 3 refined_file = open("../data/refined_data.csv", "w+")
      4 FILENAME = "../data/census2011.csv"
      5 DATA_ARRAY = [('Person ID', [])],

```

```

IOError: [Errno 2] No such file or directory: '../data/refined_data.csv'

```

The following instructions read a new file in, and check the csv file to see if it is valid. Here, a different file, 'censusmini.csv' is used, containing just 23 records, the first of which is invalid. This is a test to make sure that the invalid row is spotted, and the new refined_data file is created, without the first row.

In [2]:

```

df = pd.read_csv("../data/censusmini.csv")
check_file(DATA_ARRAY)

```

New file created with refined data

The following instructions read the actual census2011.csv file in, to ensure that it is legal.

In [3]:

```
df = pd.read_csv(FILENAME)
check_file(DATA_ARRAY)
```

```
NameErrorTraceback (most recent call last)
<ipython-input-3-7d89a3bf0554> in <module>()
----> 1 df = pd.read_csv(FILENAME)
      2 check_file(DATA_ARRAY)
```

NameError: name 'pd' is not defined

This function solves the 2nd part of the basic requirements, which is to analyse the given data. It prints out the number of records, data breakdown (the type of each variable), and the number of records for each variable value.

In [2]:

```
def data_analysis(array_of_values, FILENAME):
    number_of_rows = sum(1 for row in open(FILENAME)) - 1
    print("Number of Records: %d \n \n" % number_of_rows)

    print("Data Type Breakdown: \n\n%s\n\n" % df.dtypes)

    print("Number of Each Data Type:\n")
    counter = 0
    for (x, y) in array_of_values:
        if counter > 0:
            print(df.groupby(df[x]).size())
            counter += 1
        print("")
```

This cell simply runs the data analysis for census2011.csv.

In [5]:

```
data_analysis(DATA_ARRAY, FILENAME)
```

Number of Records: 569741

Data Type Breakdown:

```

Person ID          int64
Region             object
Residence Type     object
Family Composition int64
Population Base    int64
Sex                int64
Age                int64
Marital Status     int64
Student            int64
Country of Birth   int64
Health             int64
Ethnic Group       int64
Religion           int64
Economic Activity  int64
Occupation         int64
Industry           int64
Hours worked per week int64
Approximated Social Grade int64
dtype: object

```

Number of Each Data Type:

```

Region
E12000001    26349
E12000002    71436
E12000003    53471
E12000004    45782
E12000005    56875
E12000006    59411
E12000007    83582
E12000008    88084
E12000009    53774
W92000004    30977
dtype: int64

```

```

Residence Type
C      10654
H      559087
dtype: int64

```

```

Family Composition
-9      18851
1       96690
2      300962
3       72641
4        9848
5       64519
6        6230
dtype: int64

```

```

Population Base
1      561040
2       6730
3        1971

```

dtype: int64

Sex

1 280569

2 289172

dtype: int64

Age

1 106832

2 72785

3 75948

4 78641

5 77388

6 65666

7 48777

8 43704

dtype: int64

Marital Status

1 270999

2 214180

3 11951

4 40713

5 31898

dtype: int64

Student

1 126537

2 443204

dtype: int64

Country of Birth

-9 6804

1 485645

2 77292

dtype: int64

Health

-9 6804

1 264971

2 191744

3 74480

4 24558

5 7184

dtype: int64

Ethnic Group

-9 6804

1 483477

2 12209

3 42712

4 18786

5 5753

dtype: int64

Religion

-9 6804

1 141658

2 333481

3 2538

4 8214

```
5      2572
6     27240
7      4215
8      2406
9     40613
dtype: int64
```

Economic Activity

```
-9     112618
1      216025
2       40632
3       18109
4       14117
5       97480
6       24756
7       17945
8       17991
9       10068
dtype: int64
```

Occupation

```
-9     149984
1       39788
2       64111
3       44937
4       53254
5       48546
6       37297
7       38523
8       34818
9       58483
dtype: int64
```

Industry

```
-9     149984
1         3957
2       53433
3       30708
4       68878
5       25736
6       35240
7       16776
8       49960
9       24908
10      40560
11      49345
12      20256
dtype: int64
```

Hours worked per week

```
-9     302321
1       25776
2       52133
3      153938
4       35573
dtype: int64
```

Approximated Social Grade

```
-9     124103
1       82320
2      159642
```

```
3    79936
4    123740
dtype: int64
```

The following cells are used to implement the 3rd part of the basic requirements - the bar chart and pie chart plots. The cell below contains the implementation to create a bar chart. It takes an array of values (the legal values for what we want to plot), the variable name for this, and some variables to label the plot and the axes. Using the pandas groupby function, the number of records per variable value are found. A list of tuples is then created where the first value is the variable value, and the second is the number of records. Using this, a bar chart can be populated using the matplotlib library.

In [6]:

```
%matplotlib inline
import matplotlib.pyplot as plt
from matplotlib import cm
import operator
import numpy as np

# function that creates a bar chart using matplotlib, taking in an array which represents the
# possible range of values for the column, the column name, the name of the chart and the axes,
# and an array representing what each value in the column means.
def make_bar_chart(array_of_values, col_name, plot_name, xname, yname, text_array):
    if not type(array_of_values) == list or not type(col_name) == str or \
        not type(plot_name) == str or not type(xname) == str or not type(yname) == str:
        return
    # get the details of the column
    column = df.groupby(col_name)
    # make a list of tuples, where the first value is the name/key of the variable, and the
    # second is how many records have that value
    records = list(zip(list(column[col_name].groups.keys()),
column.size().tolist()))
    # make a list of just the names/keys in the column
    record_names = list(column[col_name].groups.keys())
    # if the possible values array size is not equal to the size of the array of records,
    # some values were missed (as no records use them), so we must add them on with value 0
    if len(records) != len(array_of_values):
        for record in array_of_values:
            if record not in record_names:
                # add the missing record with a value of 0
                records += [(record, 0)]
    # sort the records
    records.sort(key=lambda x: x[0])
    # re-fill the names array, and fill in a values array
    record_names = []
    record_values = []
    for (x, y) in records:
        record_names.append(x)
        record_values.append(y)
    # set the colours of the bar chart, trying to make them unique, by creating an array of unique colours
```

```

colours = []
colour_array = ['b', 'g', 'm', 'r', 'y', 'c', 'gold', 'burlywood', 'chartreuse',
                'maroon', 'fuchsia', 'teal', 'pink', 'grey', 'orange', 'brown',
                'w']
for x in range(0, len(array_of_values)):
    colours += [colour_array[x]]
colours = np.array(colours)
ind = range(len(records))
# set the size of the window with the bar chart
plt.figure(figsize=(18, 10))
# assign the values to the bar chart
plt.bar(ind, record_values, align='center', alpha=0.5, color=colours)
# on the x-axis, the labels should be the textual representation of the variable
values
plt.xticks(ind, text_array)
# fill in the names of the axes and the title of the chart
plt.ylabel(ystate)
plt.xlabel(xname)
plt.title(plot_name)
plt.show()

```

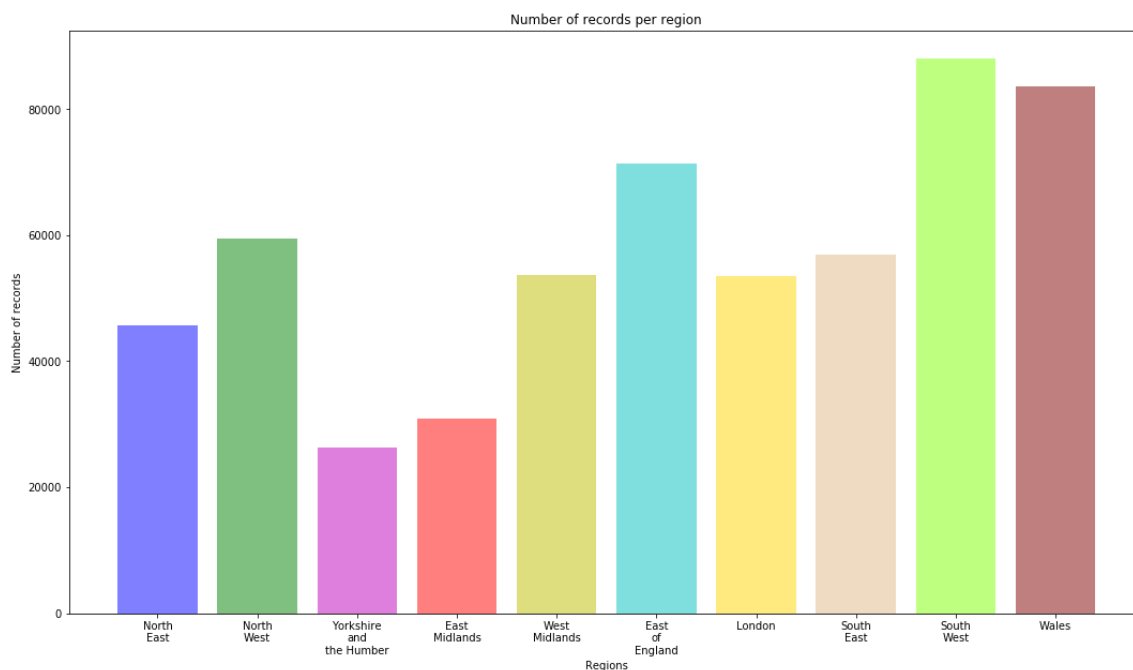
Make a bar chart for regions.

In [7]:

```

make_bar_chart(["E12000001", "E12000002", "E12000003", "E12000004", "E12000005", "E12000006",
               "E12000007", "E12000008", "E12000009", "W92000004"], 'Region',
               'Number of records per region', 'Regions', 'Number of records',
               ["North\nEast", "North\nWest", "Yorkshire\nand\nthe Humber", "East\nMidlands",
               "West\nMidlands", "East\nof\nEngland", "London", "South\nEast", "South\nWest",
               "Wales"])

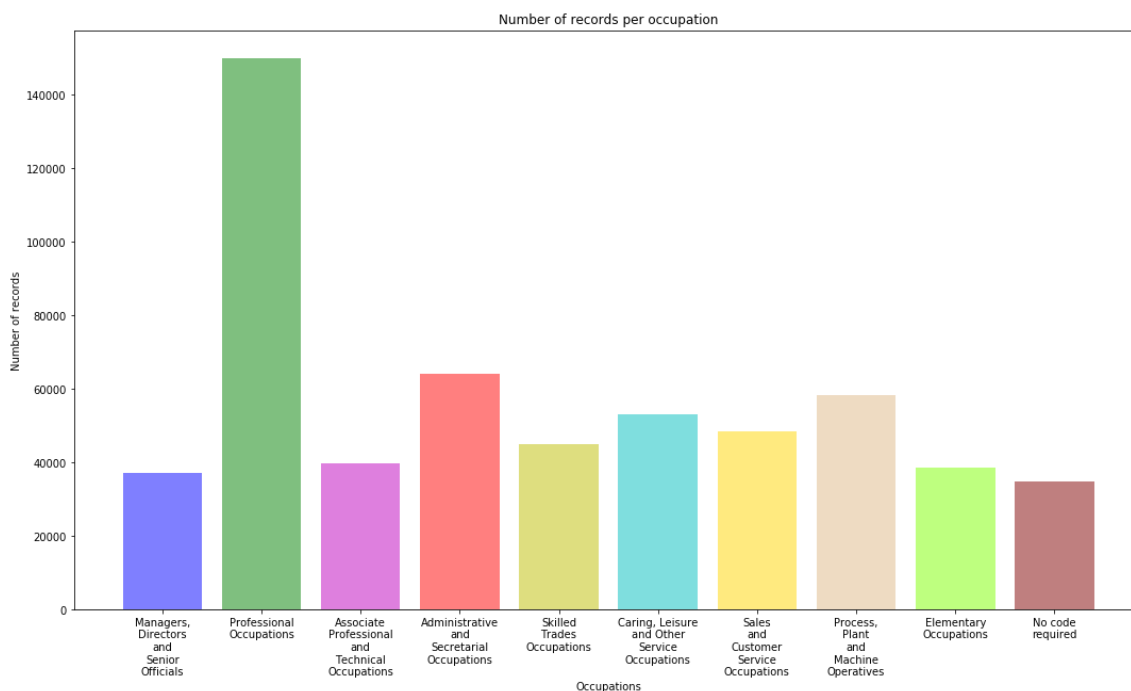
```



Make a bar chart for occupations.

In [8]:

```
make_bar_chart([-9] + list(range(1, 10)), 'Occupation', 'Number of records per occupation',
               'Occupations', 'Number of records',
               ["Managers,\nDirectors\nand\nSenior\nOfficials",
                "Professional\nOccupations",
                "Associate\nProfessional\nand\nTechnical\nOccupations",
                "Administrative\nand\nSecretarial\nOccupations",
                "Skilled\nTrades\nOccupations",
                "Caring, Leisure\nand Other\nService\nOccupations",
                "Sales\nand\nCustomer\nService\nOccupations",
                "Process,\nPlant\nand\nMachine\nOperatives",
                "Elementary\nOccupations",
                "No code\nrequired"])
```



Function used to make a pie chart. In a similar way to the above function, groupby is used to get the number of records, which are then plotted on a pie chart using matplotlib. The colours are set to be unique so that the legend can be used to make the data more clear, however we have found that each computer in the labs interprets this differently, and therefore sometimes the colours are not unique. With the following code, it seems to work the best.

In [9]:

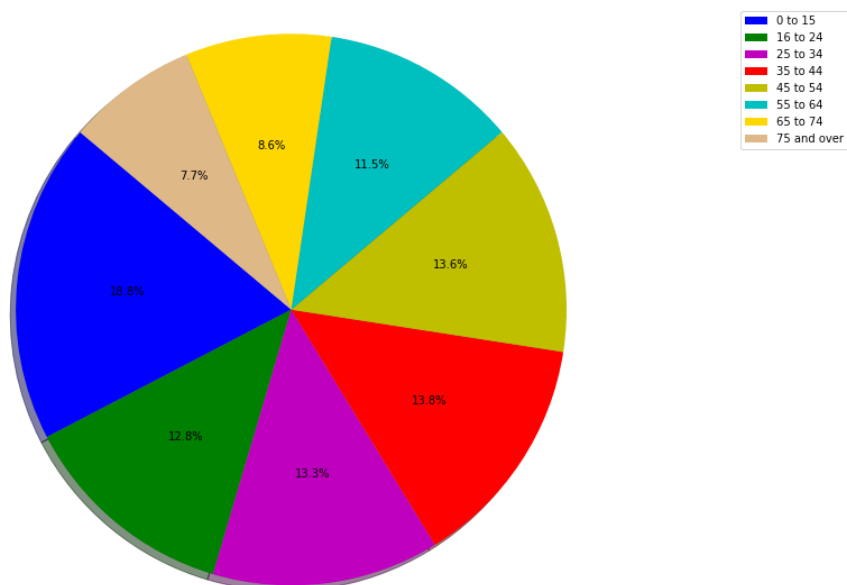
```
# function which makes a pie chart based on number of records that have the same
# value for the given column name. Possible values are given as a list, and
# another list of text to show what each value means
def make_pie_chart(array_of_values, col_name, text_array):
    if not type(array_of_values) == list or not type(col_name) == str:
        return
    # get the details of the column
    column = df.groupby(col_name)
    # create a list of the number of records that have the same value for the column
    record_numbers = column.size().tolist()
    # if the possible values array size is not equal to the size of the array of records,
    # some values were missed (as no records use them), so we must add them on with value 0
    if len(array_of_values) != len(record_numbers):
        for x in range(0, len(array_of_values) - len(record_numbers)):
            # add the missing record with a value of 0
            record_numbers += [0]
    # set the colours of the pie chart, trying to make them unique, by creating an array of unique colours
    colours = []
    colour_array = ['b', 'g', 'm', 'r', 'y', 'c', 'gold', 'burlywood', 'chartreuse',
                    'maroon', 'fuchsia', 'teal', 'pink', 'grey', 'orange', 'brown',
                    'w']
    for x in range(0, len(array_of_values)):
        colours += [colour_array[x]]
    colours = np.array(colours)

    # root.mainloop()
    # set the size of the window with the pie chart
    plt.figure(figsize=(18, 10))
    # add the record numbers to the pie chart along with the colours
    plt.pie(record_numbers, colors=colours, autopct='%1.1f%%', shadow=True, startangle=140)
    # add a legend to explain what each variable means
    plt.legend(text_array, loc="upper right")
    plt.axis('equal')
    plt.show()
```

Make a pie chart for the age variable.

In [10]:

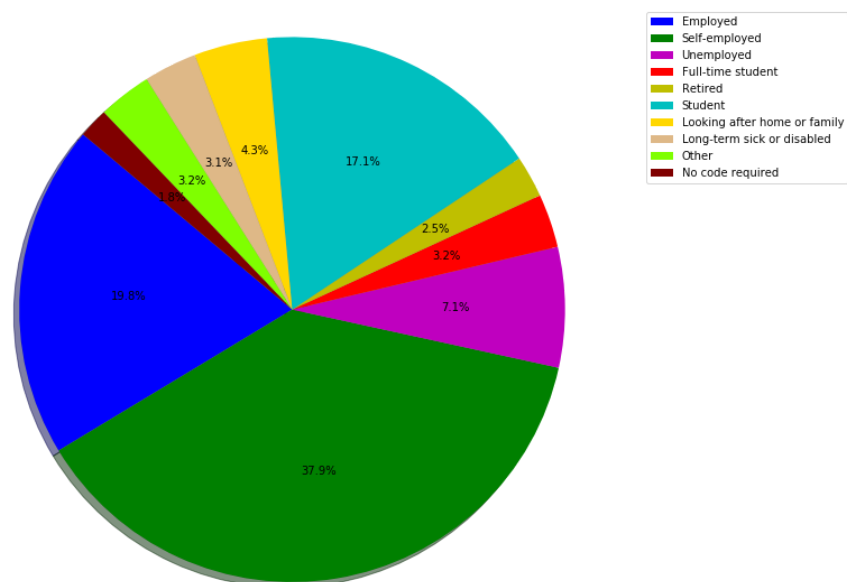
```
make_pie_chart(list(range(1, 9)), 'Age', TEXT_ARRAY[6][1])
```



Make a pie chart for the economic activity variable.

In [11]:

```
make_pie_chart([-9] + list(range(1, 10)), 'Economic Activity',  
TEXT_ARRAY[13][1])
```



The following function contains the implementation for the first Easy extension. It is used to make a table, using the `texttable` library. Similarly to the above functions, `groupby` is used to get the number of records per variable value, and a list of tuples is created. The first value of this tuple is the first variable name, and the second is the second variable name. The total number of records is held in `table_values`. Once the correct number of 0s have been added to the values (to not ignore variable values that didn't have records), the function uses `texttable` to print the heading of the table (first variable values), and then all the rows with the values (the first of which is the second variable value). Finally, the actual text explanations for the variables are used rather than just the values on the table, in order to meet the requirements.

In [12]:

```
import operator
import texttable as tt

# function to create a table, showing the number of records that have the same
# values for a two given columns. The first column is col, the second is row (as it
# is
# displayed in this way on a table). The two arrays are the possible values of these
# columns,
# the table name is the title of the table, and the text arrays represent what each
# value means
def make_table(col, row, array_of_values_col, array_of_values_row, table_name, col_text_array, row_text_array):
    if not type(col) == str or not type(row) == str or not type(array_of_values_col) == list \
        or not type(array_of_values_row) == list or not type(table_name) == str:
        return
    # try and print out the table name in around the centre of the table at the top
    for x in range(0, len(array_of_values_col) * 60 // len(table_name)):
        table_name = " " + table_name
    print(table_name + '\n')
    # get the number of records that have the same values for the given columns as a
    list
    table_values = df.groupby([col, row]).size().tolist()
    # get a list of tuples containing the key and value, and sort by value
    table_headings = sorted(df.groupby([col, row]).groups.keys(), key=operator.itemgetter(1))
    # sort the same list by key, so it is properly sorted now
    table_headings = sorted(table_headings, key=operator.itemgetter(0))
    # keep track of where we are in the table values
    counter = 0
    # add 0s in the right places for the missing values
    # go through each item of the first array
    for item in array_of_values_col:
        # go through each item of the second array
        for val in array_of_values_row:
            # if the given tuple of items isn't in the list
            if (item, val) not in table_headings:
                # add a 0 on to the array of all the values in the right place
                table_values.insert(counter, 0)
            counter += 1
    # use texttable to create a nice table
    table = tt.Texttable()
    # insert a blank line at the start (as the first column will have the row names)
    col_text_array.insert(0, " ")
    # add the header of the table, which will be the textual representation of the possible values
```

```
# for the first column
table.header(col_text_array)
# for the first row, add the first value of the row text array
new_row = [row_text_array[0]]
# keep track of the rows added
counter = 1
# go through all the values in the table of values and add them to each row on the table
for x in range(0, len(table_values)):
    # if the length of the row is the length of the possible values of the first column
    if len(new_row) == len(col_text_array):
        # add the row to the table
        table.add_row(new_row)
        # set the new row equal to the name of the next value in the text array
        new_row = [row_text_array[counter]]
        counter += 1
    # add the next value to the row
    new_row.append(table_values[x])
    x += 1
# print the table
s = table.draw()
print(s)
print('\n\n\n')
```

Create a table for number of records by regions and industry. The long lists in the arguments contain the explanations to each variable value in the given variable.

In [13]:

```
make_table('Region', 'Industry', ["E12000001", "E12000002", "E12000003",  
"E12000004",  
                                "E12000005", "E12000006", "E12000007",  
"E12000008",  
                                "E12000009", "W92000004"], [-9] + list(range(1,  
13)),  
          "NUMBER OF RECORDS BY REGION AND INDUSTRY",  
          TEXT_ARRAY[1][1],  
          TEXT_ARRAY[15][1])
```

	North	North	York	East	West	East	Lond	Sout	Sout
Wale	h	h	shir	Midl	Midl	of E	on	h	h
s	East	West	e	ands	ands	ngla		East	West
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Mini	1836	2524	848	1875	357	7726	3778	9016	3355
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3028										
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tion										
+-----+	+-----+	+-----+	+-----+	+-----+	+-----+	+-----+	+-----+	+-----+	+-----+	+-----+
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Whol	6670	2555	2788	1284	4046	2141	3961	4855	1736	
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and										
food										
serv										
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acti										
viti										
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+-----+										
Tran	3952	1414	1576	396	7108	2960	7067	2281	3141	
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Finan	4284	2061	3984	4848	1828	1474	616	5302	3508
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Publ	3266	3700	8204	4054	6570	4016	9968	3015	5373	
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Educ	3735	2224	510	6651	4896	1054	3566	6502	3059
8708									
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+-----+									
Huma	4145	6593	7344	3316	1240	697	5012	3033	6899
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Othe	2961	1510	4475	2973	4039	5085	1977	7937	403
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Make a table for number of records by occupation and social grade.

In [14]:

```
make_table('Occupation', 'Approximated Social Grade', [-9, 1, 2, 3, 4, 5, 6, 7, 8, 9],  
           [-9, 1, 2, 3, 4], "NUMBER OF RECORDS BY OCCUPATION AND SOCIAL GRADE",  
           TEXT_ARRAY[14][1],  
           TEXT_ARRAY[17][1])
```

NUMBER OF RECORDS BY OCCUPATION AND SOCIAL GRADE

	Mana	Prof	Asso	Admi	Skil	Cari	Sale	Proc	Elem	
No	gers	essi	ciat	nist	led	ng,	s	ess,	enta	
code	, Di	onal	e Pr	rati	Trad	Leis	and	Plan	ry 0	
requ	rect	Occu	ofes	ve	es 0	ure	Cust	t	ccup	
ired	ors	pati	sion	and	ccup	and	omer	and	atio	
	and	ons	al	Secr	atio	0the	Serv	Mach	ns	
	Seni		and	etar	ns	r Se	ice	ine		
	or 0		Tech	ial		r vic	Occu	Oper		
	ffic		nica	Occu		e 0c	pati	ativ		
	ials		l 0c	pati		cupa	ons	es		
			cupa	ons		tion				
			tion			s				
			s							
AB	1169	1051	1778	2062	1216	492	1919	1855	584	
967	15		7		9		0	5		
C1	884	4810	1322	891	1009	819	7050	3543	647	
986		4	3					5		
C2	727	3000	4492	2353	2252	678	585	2464	3719	
7629			2						0	
DE	478	1061	6343	1555	1386	1031	964	1218	2997	
2134				5	0			4		
7										

The following cell contains the implementation to the first Medium extension, which is to create 3d plots for the tables used above. The `mpl_toolkits.mplot3d` library was used. To get the values for each variable, the same method was used as in the `make_table` function, using `groupby` and by using a list of values, and a list of tuples (for the variable values). Once this was done, the x axis was assigned to a list of values of the first variable, the y axis to the second variable, and the z axis to the number of records. Using the `numpy` library, the arrays are re-shaped to fit on the grid, and then the plot is drawn.

In [15]:

```

from mpl_toolkits.mplot3d import Axes3D
import numpy as np

# function to make a 3d plot where one axis is the given column name's possible values,
# the second is the same for the second column (row), and the third is the number of records
# that have the same values for the given columns. The arrays given represent the
# possible values that these columns can have
def make_3d(col, row, array_of_values_col, array_of_values_row, col_text_array,
            row_text_array):
    if not type(col) == str or not type(row) == str or not type(array_of_values_col)
    == list \
        or not type(array_of_values_row) == list:
        return
    # get the number of records that have the same values for the given columns as a
    list
    values = df.groupby([col, row]).size().tolist()
    # get a list of tuples containing the key and value, and sort by value
    axes_values = sorted(df.groupby([col, row]).groups.keys(), key=operator.itemgetter
    er(1))
    # sort the same list by key, so it is properly sorted now
    axes_values = sorted(axes_values, key=operator.itemgetter(0))
    # keep track of where we are in the values
    counter = 0
    # add 0s in the right places for the missing values
    # go through each item of the first array
    for item in array_of_values_col:
        # go through each item of the second array
        for val in array_of_values_row:
            # if the given tuple of items isn't in the list
            if (item, val) not in axes_values:
                # add a 0 on to the array of all the values in the right place
                values.insert(counter, 0)
            counter += 1
    # create the figure, set the size
    fig = plt.figure(figsize=(16, 8))
    ax = fig.add_subplot(111, projection='3d')
    # add the right values to the x and y axes
    x = list(range(0, len(array_of_values_col)))
    y = list(range(0, len(array_of_values_row)))
    # re-shape the axes
    X, Y = np.meshgrid(x, y)
    # set the z axis to the array of values
    zs = np.array(values)
    # re-shape to fit in the axis
    Z = zs.reshape(X.shape)

    ax.plot_surface(X, Y, Z)

```

```

# set the axes values
ax.set_xticks(x)
ax.set_yticks(y)
# set the axes labels
ax.set_xticklabels(np.array(col_text_array))
ax.set_yticklabels(np.array(row_text_array))
# set the names of the axes
ax.set_xlabel("\n\n\n\n\n" + str(col))
ax.set_ylabel("\n\n\n\n\n" + str(row))
ax.set_zlabel('Number of Records')

plt.show()

```

Create a 3d plot for number of records by regions and industry. The long lists in the arguments contain the explanations to each variable value in the given variable.

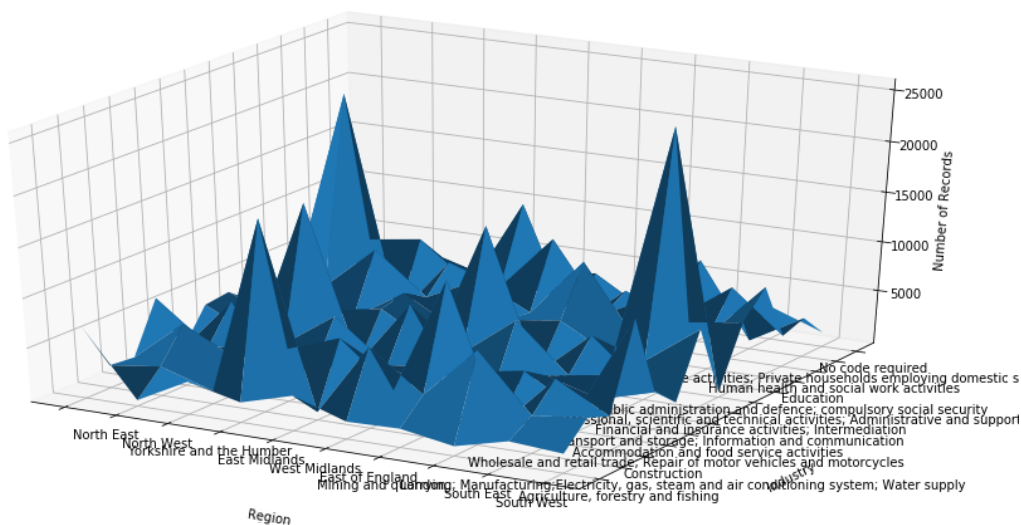
In [16]:

```

make_3d('Region', 'Industry', ["E12000001", "E12000002", "E12000003", "E12000004",
                                "E12000005", "E12000006", "E12000007", "E12000008",
                                "E12000009", "W92000004"], [-9] + list(range(1, 13)),

        TEXT_ARRAY[1][1],
        TEXT_ARRAY[15][1])

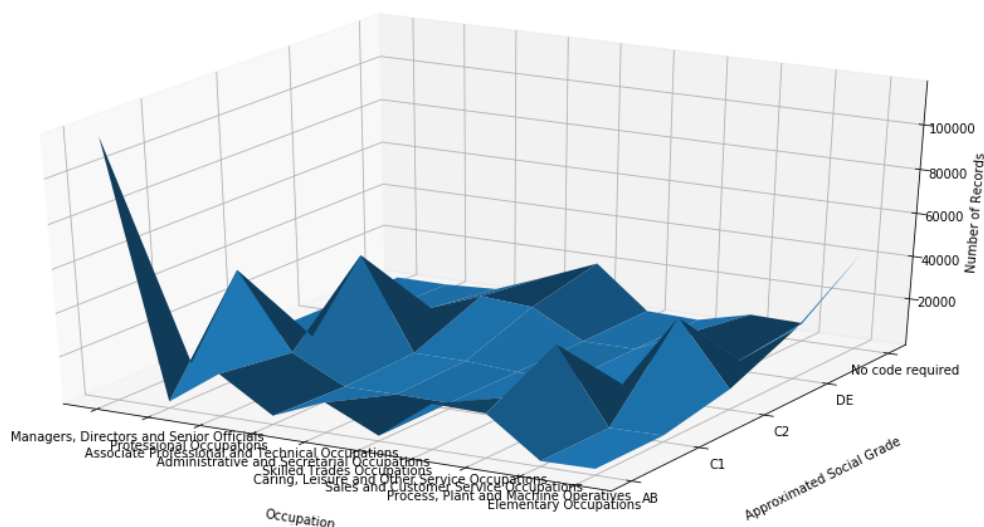
```



Make a 3d plot for number of records by occupation and social grade.

In [17]:

```
make_3d('Occupation', 'Approximated Social Grade', [-9, 1, 2, 3, 4, 5, 6, 7, 8, 9],
        [-9, 1, 2, 3, 4],
        TEXT_ARRAY[14][1],
        TEXT_ARRAY[17][1])
```



The following cell implements the second Easy extension, which is to make plots based on different queries. A bar chart representation was used. The function is the same as the one above to make a bar chart, except it takes in 2 more arguments: a variable name, and the list of values that the records should have for that variable to pass the query. This is implemented when the values are found using groupby, so only the records that match the query are counted.

In [18]:

```
# function just like the one above, except the bar chart created has an added query to it
# which the records must follow, therefore the function takes in the column name of the query
# and the range that the records' values must be in (for the given column)
def make_bar_chart_query(array_of_values, col_name, plot_name, xname, yname,
                        query_col_name, query_range, text_array):
    if not type(array_of_values) == list or not type(col_name) == str or \
        not type(plot_name) == str or not type(xname) == str or not type(yname)
== str \
        or not type(query_col_name) == str or not type(query_range) == list:
        return
    # get the details of the column with the query applied, making sure the records
# counted follow the query
    column = df.loc[df[query_col_name].isin(query_range)].groupby(col_name)
    # make a list of tuples, where the first value is the name/key of the variable,
and the
    # second is how many records have that value
    records = list(zip(list(column[col_name].groups.keys()),
column.size().tolist()))
    # make a list of just the names/keys in the column
    record_names = list(column[col_name].groups.keys())
    # if the possible values array size is not equal to the size of the array of rec
ords,
    # some values were missed (as no records use them), so we must add them on with
value 0
```

```

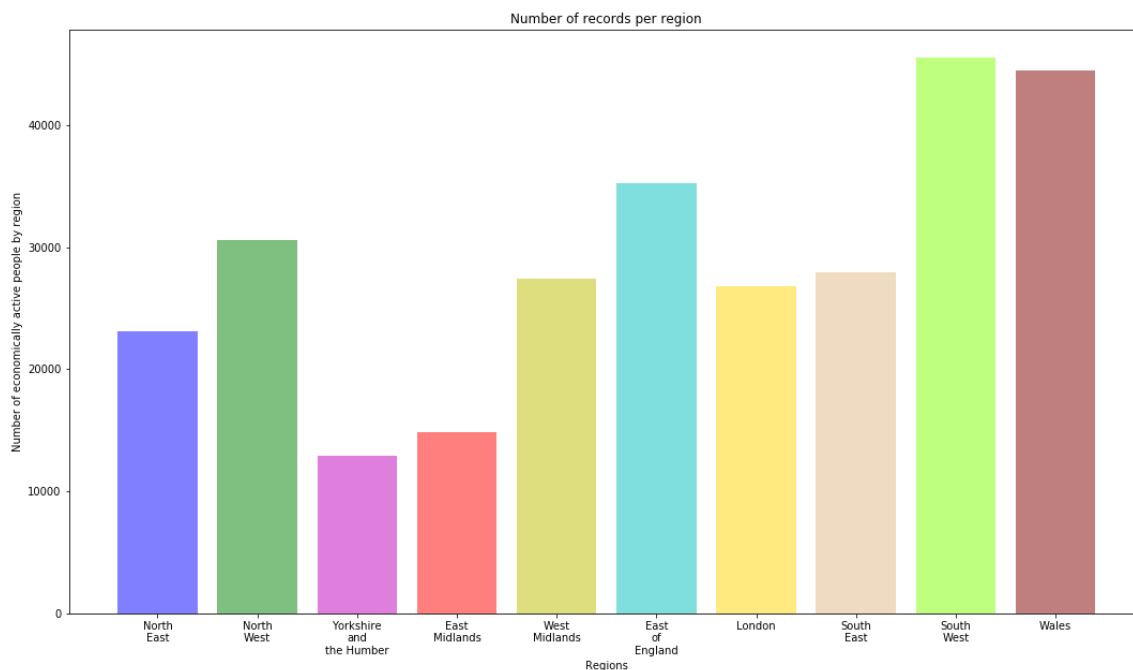
if len(records) != len(array_of_values):
    for record in array_of_values:
        if record not in record_names:
            # add the missing record with a value of 0
            records += [(record, 0)]
# set the colours of the bar chart, trying to make them unique, by creating an array of unique colours
colours = []
colour_array = ['b', 'g', 'm', 'r', 'y', 'c', 'gold', 'burlywood', 'chartreuse',
                'maroon', 'fuchsia', 'teal', 'pink', 'grey', 'orange', 'brown',
                'w']
for x in range(0, len(array_of_values)):
    colours += [colour_array[x]]
colours = np.array(colours)
# sort the records
records.sort(key=lambda x: x[0])
# re-fill the names array, and fill in a values array
record_names = []
record_values = []
for (x, y) in records:
    record_names.append(x)
    record_values.append(y)
ind = range(len(records))
# set the size of the window with the bar chart
plt.figure(figsize=(18, 10))
# assign the values to the bar chart
plt.bar(ind, record_values, align='center', alpha=0.5, color=colours)
# on the x-axis, the labels should be the textual representation of the variable
values
plt.xticks(ind, text_array)
# fill in the names of the axes and the title of the chart
plt.ylabel(yname)
plt.xlabel(xname)
plt.title(plot_name)
plt.show()

```

Make a bar chart of number of economically active people (economic activity 1-4) by region.

In [19]:

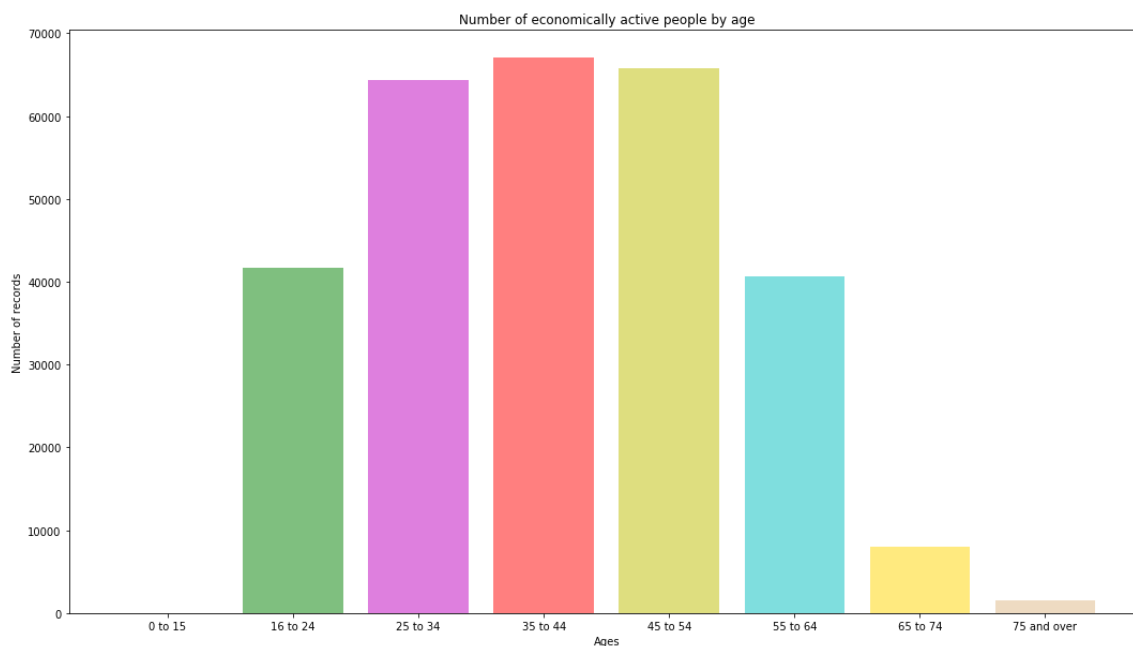
```
make_bar_chart_query(["E12000001", "E12000002", "E12000003", "E12000004", "E12000005", "E12000006",
                    "E12000007", "E12000008", "E12000009", "W92000004"], 'Region',
                    'Number of records per region', 'Regions',
                    'Number of economically active people by region', 'Economic Act
ivity',
                    list(range(1, 5)),
                    ["North\nEast", "North\nWest", "Yorkshire\nand\nthe Humber",
                    "East\nMidlands", "West\nMidlands", "East\nof\nEngland", "Lond
on",
                    "South\nEast", "South\nWest", "Wales"])
```



Make a bar chart of number of economically active people (economic activity 1-4) by age.

In [20]:

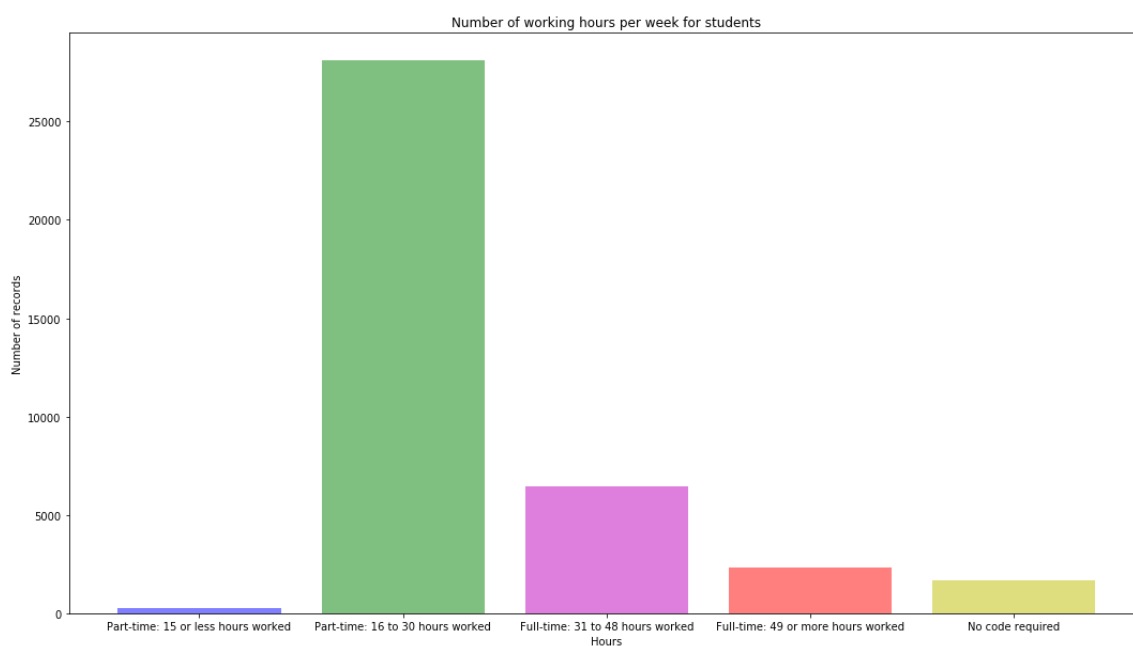
```
make_bar_chart_query(list(range(1, 9)), 'Age',
                     'Number of economically active people by age', 'Ages', 'Number
of records',
                     'Economic Activity', list(range(1, 5)),
                     TEXT_ARRAY[6][1])
```



Make a bar chart of number of working hours per week for students (economic activity 4 or 6)

In [21]:

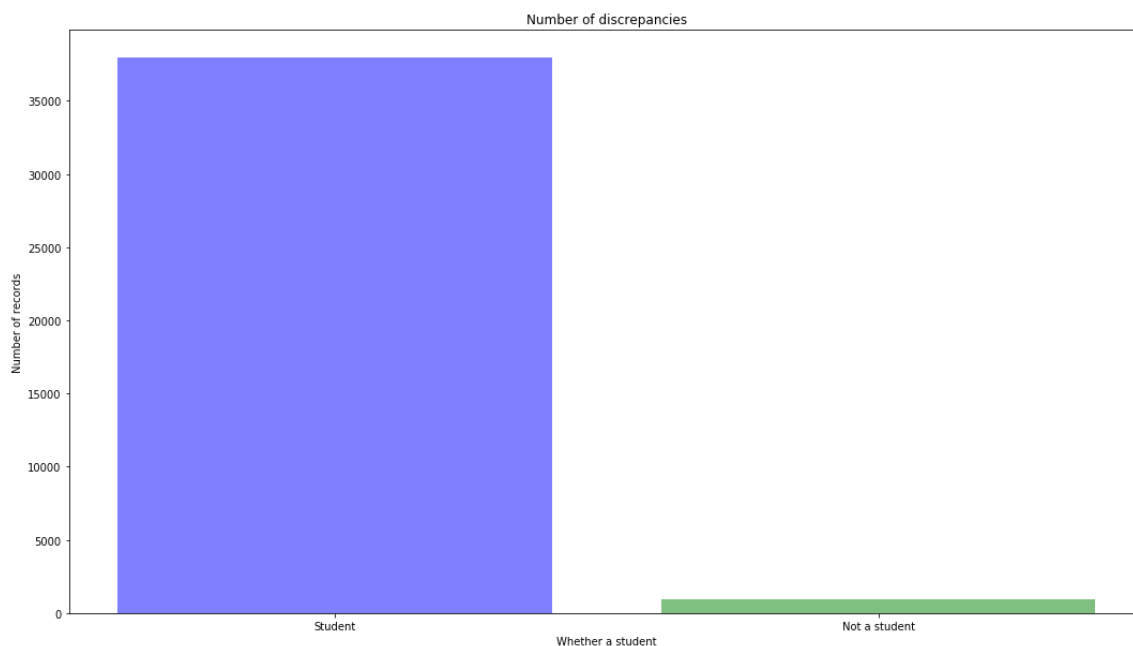
```
make_bar_chart_query([-9] + list(range(1, 5)), 'Hours worked per week',
                     'Number of working hours per week for students', 'Hours',
                     'Number of records', 'Economic Activity', [4, 6],
                     TEXT_ARRAY[16][1])
```



Make a bar chart to check for discrepancies between the student status given as a yes/no answer to the question "Student (Schoolchild or full-time student)" and answers on the question on "Economic activity" (should be 4 or 6 if they are a student, which is the query). So, any records displayed that aren't students (value 2) have a discrepancy.

In [22]:

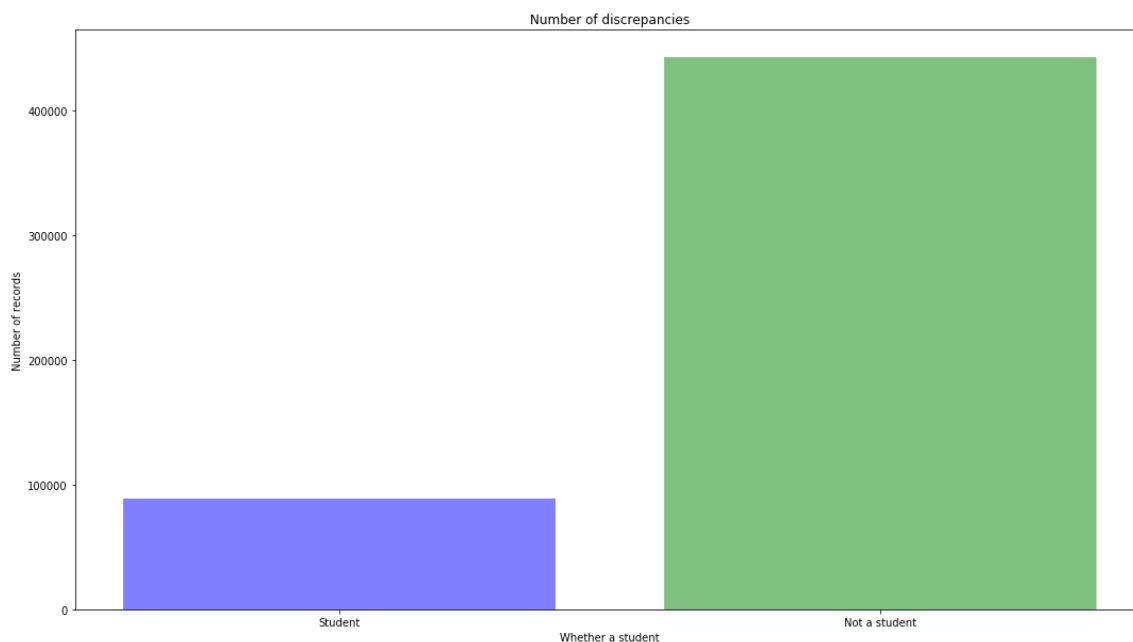
```
make_bar_chart_query([1, 2], 'Student',
                      'Number of discrepancies', 'Whether a student',
                      'Number of records', 'Economic Activity', [4, 6], TEXT_ARRAY[8]
[1])
```



Similar to the above command, make a bar chart to check for discrepancies between the student status given as a yes/no answer to the question "Student (Schoolchild or full-time student)" and answers on the question on "Economic activity" (should not be 4 or 6 if they are not a student, which is the query). So, any records displayed that are students (value 1) have a discrepancy.

In [23]:

```
make_bar_chart_query([1, 2], 'Student',
                     'Number of discrepancies', 'Whether a student',
                     'Number of records', 'Economic Activity', [-9, 1, 2, 3, 5, 7,
8, 9], TEXT_ARRAY[8][1])
```



Implementation for the 2nd Medium extension, which is to use ipywidgets to get different record numbers. This is how we interpreted the extension, because we didn't think it would make sense to create a plot based on 2 values (e.g. 1 region, 1 industry). Therefore, this function creates one dropdown widget and one selection slider widget (as the selection isn't always an exact range of values), and based on the selected values, prints out the number of records that have both those values. Firstly, the widgets are created, and then a similar implementation to the `make_table` function is used to create an array of all the record numbers, and an array of tuples containing the values of each variable. When the "select" option is picked from the dropdown widget, nothing is printed. As soon as this changes, or if the slider changes value, the `change_num` function is called, which finds the appropriate index in the array of tuples where the 2 values are located, and prints the number at the same index in the array of record numbers, as this will be the appropriate value.

In [24]:

```

from ipywidgets import widgets
from IPython.display import display
import operator

def get_value_with_widgets(col, row, array_of_values_col, array_of_values_row):

    dropdown = widgets.Dropdown(options=["Select"] + array_of_values_col,
                                description=col + ": ",
                                value="Select")
    slider = widgets.SelectionSlider(options=array_of_values_row, description=row +
": ")
    display(dropdown)
    display(slider)
    # get the number of records that have the same values for the given columns as a
list
    table_values = df.groupby([col, row]).size().tolist()
    # get a list of tuples containing the key and value, and sort by value
    table_headings = sorted(df.groupby([col, row]).groups.keys(), key=operator.itemg
etter(1))
    # sort the same list by key, so it is properly sorted now
    table_headings = sorted(table_headings, key=operator.itemgetter(0))
    # keep track of where we are in the table values
    counter = 0
    # add 0s in the right places for the missing values
    # go through each item of the first array
    for item in array_of_values_col:
        # go through each item of the second array
        for val in array_of_values_row:
            # if the given tuple of items isn't in the list
            if (item, val) not in table_headings:
                # add a 0 on to the array of all the values in the right place
                table_values.insert(counter, 0)
            counter += 1
    # Define function to bind value of the input to the output variable

    def change_num(change):
        if change['type'] == 'change' and change['name'] == 'value' and dropdown.val
ue != "Select":
            col_row_value = (dropdown.value, slider.value)
            counter = -1
            for x in range(0, len(table_headings)):
                if table_headings[x] == col_row_value:
                    counter = x
                    break
            if counter != -1:
                print(str(col_row_value) + " = " + str(table_values[counter]) + " re
cords")
            dropdown.observe(change_num)
            slider.observe(change_num)

```

Create widgets for region and industry, interacting with them prints out the number of records for the chosen values.

In [25]:

```
get_value_with_widgets('Region', 'Industry',
                        ["E12000001", "E12000002", "E12000003", "E12000004",
                         "E12000005", "E12000006", "E12000007", "E12000008",
                         "E12000009", "W92000004"],
                        [-9] + list(range(1, 13)))
```

The same function as the above, except it creates 2 selection sliders rather than 1 dropdown and 1 selection slider. This was done to create some variety and give the user options on what type of representation they want to use.

In [26]:

```
def get_value_with_widgets2(col, row, array_of_values_col, array_of_values_row):

    slider = widgets.SelectionSlider(options=["Select"] + array_of_values_col,
                                     description=col + ": ")
    slider2 = widgets.SelectionSlider(options=array_of_values_row, description=row +
    ": ")
    display(slider)
    display(slider2)
    # get the number of records that have the same values for the given columns as a
    list
    table_values = df.groupby([col, row]).size().tolist()
    # get a list of tuples containing the key and value, and sort by value
    table_headings = sorted(df.groupby([col, row]).groups.keys(), key=operator.itemgetter(1))
    # sort the same list by key, so it is properly sorted now
    table_headings = sorted(table_headings, key=operator.itemgetter(0))
    # keep track of where we are in the table values
    counter = 0
    # add 0s in the right places for the missing values
    # go through each item of the first array
    for item in array_of_values_col:
        # go through each item of the second array
        for val in array_of_values_row:
            # if the given tuple of items isn't in the list
            if (item, val) not in table_headings:
                # add a 0 on to the array of all the values in the right place
                table_values.insert(counter, 0)
                counter += 1
    # Define function to bind value of the input to the output variable

    def change_num(change):
        if change['type'] == 'change' and change['name'] == 'value' and slider.value
        != "Select":
            col_row_value = (slider.value, slider2.value)
            counter = -1
            for x in range(0, len(table_headings)):
                if table_headings[x] == col_row_value:
                    counter = x
                    break
            if counter != -1:
                print(str(col_row_value) + " = " + str(table_values[counter]) + " re
                cords")
            slider.observe(change_num)
            slider2.observe(change_num)
```

Create widgets for occupation and social grade, interacting with them prints out the number of records for the chosen values.

In [27]:

```
get_value_with_widgets2('Occupation', 'Approximated Social Grade', [-9, 1, 2, 3, 4,
5, 6, 7, 8, 9],
                        [-9, 1, 2, 3, 4])
```

The following functions are used to implement the first hard extension, which is to create an interactive map, where the user can select a region. This will display a pie chart based on a variable, selected by the user, using a dropdown widget, which is an extension to the extension. The image used as the background has been downloaded from google images. The tkinter library was used to create the GUI. When using the make_map function, make sure to close the map before selecting a value from the dropdown list, as only 1 region can be selected each time this is run.

In [28]:

```
from tkinter import *

# list of all the variables
variable_list = []
# list of range of values for specific variable
range_list = []
# populate the variable list
for (x, y) in DATA_ARRAY:
    if y:
        variable_list += [x]

# create the dropdown widget with the options
dropdown = widgets.Dropdown(options=["Select"] + variable_list,
                             description="Variable: ",
                             value="Select")

# function which makes a pie chart based on number of records that have the same
# value for the given column name. Possible values are given as a list, and
# another list of text to show what each value means. Finally, there is an added query,
# meaning the record numbers are only counted for the records that pass the query. The query will
# always be based on the region the way it is used with the map
def make_pie_chart_query(array_of_values, col_name, text_array, query_col_name, query_range):
    if not type(array_of_values) == list or not type(col_name) == str:
        return
    # get the details of the column with the added query
    column = df.loc[df[query_col_name].isin(query_range)].groupby(col_name)
    # create a list of the number of records that have the same value for the column
    record_numbers = column.size().tolist()
    # if the possible values array size is not equal to the size of the array of records,
    # some values were missed (as no records use them), so we must add them on with value 0
    if len(array_of_values) != len(record_numbers):
        for x in range(0, len(array_of_values) - len(record_numbers)):
```

```

        # add the missing record with a value of 0
        record_numbers += [0]
    # set the colours of the pie chart, trying to make them unique, by creating an a
    rray of unique colours
    colours = []
    colour_array = ['b', 'g', 'm', 'r', 'y', 'c', 'gold', 'burlywood', 'chartreuse',
                    'maroon', 'fuchsia', 'teal', 'pink', 'grey', 'orange', 'brown',
                    'w']
    for x in range(0, len(array_of_values)):
        colours += [colour_array[x]]
    colours = np.array(colours)

    # root.mainloop()
    # set the size of the window with the pie chart
    plt.figure(figsize=(10, 8))
    # add the record numbers to the pie chart along with the colours
    plt.pie(record_numbers, colors=colours, autopct='%1.1f%%', shadow=True, startang
le=140)
    # add a legend to explain what each variable means
    plt.legend(text_array, loc="upper right")
    plt.axis('equal')
    plt.show()

# callback function for when a region is chosen
def button_clicked(region_code):

    # function to create a pie chart when a value is selected from the dropdown list
    def show_chart(change):
        # make sure 'Select' isn't selected
        if change['type'] == 'change' and change['name'] == 'value' and dropdown.val
ue != "Select":
            range_list = []
            text = []
            # populate the range list by finding the right one from the DATA_ARRAY
            for (x, y) in DATA_ARRAY:
                if y and x == dropdown.value:
                    range_list = y
                    break
            # similarly, populate the text list
            for (w, z) in TEXT_ARRAY:
                if w == dropdown.value:
                    text = z
                    break
            # make the pie chart with the selected region (this is the query)
            make_pie_chart_query(range_list, dropdown.value, text, 'Region', [region
_code])

        dropdown.observe(show_chart)
        display(dropdown)

# create the GUI with the map and the buttons on the regions
def make_map():
    window = Tk()
    window.title("map")
    # set image as background image
    bg_image = PhotoImage(file="../data/uk_map_regional_consortia_web.gif")
    x = Label(image=bg_image)
    x.grid(row=0, column=0)
    # create all the buttons, the abbreviations in their names represent their regio

```

```

n (NE = North East)
# the x and y values for the buttons are exact and place the buttons on their appropriate regions
bNE = Button(window, text="NORTH\nEAST", width=3,
              command=lambda: button_clicked("E12000001"),
              background='lightblue', activebackground='red')
bNE.place(relx=.6, rely=.15, anchor="c")
bNW = Button(window, text="NORTH\nWEST", width=3,
              command=lambda: button_clicked("E12000002"),
              background='lightblue', activebackground='red')
bNW.place(relx=.465, rely=.2, anchor="c")
bYH = Button(window, text="YORKSHIRE\nAND THE\nHUMBER", width=8,
              command=lambda: button_clicked("E12000003"),
              background='lightblue', activebackground='red')
bYH.place(relx=.67, rely=.33, anchor="c")
bEM = Button(window, text="EAST\nMIDLANDS", width=6,
              command=lambda: button_clicked("E12000004"),
              background='lightblue', activebackground='red')
bEM.place(relx=.7, rely=.5, anchor="c")
bWM = Button(window, text="WEST\nMIDLANDS", width=6,
              command=lambda: button_clicked("E12000005"),
              background='lightblue', activebackground='red')
bWM.place(relx=.5, rely=.58, anchor="c")
bEE = Button(window, text="EAST\nENGLAND", width=7,
              command=lambda: button_clicked("E12000006"),
              background='lightblue', activebackground='red')
bEE.place(relx=.85, rely=.65, anchor="c")
bL = Button(window, text="LONDON", width=4,
              command=lambda: button_clicked("E12000007"),
              background='lightblue', activebackground='red')
bL.place(relx=.75, rely=.77, anchor="c")
bSE = Button(window, text="SOUTH\nEAST", width=8,
              command=lambda: button_clicked("E12000008"),
              background='lightblue', activebackground='red')
bSE.place(relx=.7, rely=.878, anchor="c")
bSW = Button(window, text="SOUTH\nWEST", width=8,
              command=lambda: button_clicked("E12000009"),
              background='lightblue', activebackground='red')
bSW.place(relx=.33, rely=.85, anchor="c")
bW = Button(window, text="\nWALES\n", width=6,
              command=lambda: button_clicked("W92000004"),
              background='lightblue', activebackground='red')
bW.place(relx=.30, rely=.62, anchor="c")
window.mainloop()

```

Use the above function to create a map. When a region is selected, make sure to close the map before selecting a value from the dropdown list, as it will only be triggered when the map is closed. Therefore, only 1 region can be selected each time this is run.

In [29]:

```
make_map()
```

The following cell contains the implementation for the 2nd hard extension, which is to analyse other data sets. Due to our previous functions being reproduceable/reusable, all that needs to be done is to create a data array with the new variables and their details, a new refined file and a new filename. The commands are the same and the same functions are used as before. Of course, all of the above functions

In [30]:

```
# array of data for schoolattendance.csv, each variable with possible range of values per tuple
DATA_ARRAY = [('GeographyCode', []),
               ("DateCode", ["2003-2004", "2004-2005", "2005-2006", "2006-2007", "2007-2008", "2008-2009", "2009-2010", "2010-2011"]),
               ("Measurement", ["Ratio"]),
               ("Units", ["Percentage"]),
               ("Value", [round(x * 0.01, 2) for x in range(0, 10001)]),
               ("School Type", ["Primary", "Secondary"])]
refined_file = open("../data/refined_data_2.csv", "w+")
filename = "../data/schoolattendance.csv"
```

Similarly as before, simply read in the new file using pandas and check that the file is legal

In [31]:

```
df = pd.read_csv(filename)
check_file(DATA_ARRAY)
```

All records are legal - no new file needed

Perform data analysis on the new file

In [32]:

```
data_analysis(DATA_ARRAY, filename)
```

Number of Records: 135252

Data Type Breakdown:

GeographyCode object
DateCode object
Measurement object
Units object
Value float64
School Type object
dtype: object

Number of Each Data Type:

DateCode
2003-2004 16808
2004-2005 16917
2005-2006 16917
2006-2007 16922
2007-2008 16922
2008-2009 16922
2009-2010 16922
2010-2011 16922
dtype: int64

Measurement
Ratio 135252
dtype: int64

Units
Percentage 135252
dtype: int64

Value
0.00 34
46.36 2
50.69 1
55.88 1
57.11 1
58.10 1
59.11 1
59.47 4
64.65 1
65.07 1
65.46 1
65.53 1
65.96 1
66.01 1
66.19 1
66.59 2
67.02 1
67.17 1
67.33 1
67.84 1
68.12 1
68.26 1
68.41 2
68.50 1

68.59	1
69.57	1
70.20	1
70.34	1
70.36	1
70.41	1

..

99.06	2
99.08	1
99.09	1
99.10	1
99.12	1
99.13	4
99.14	2
99.15	1
99.16	1
99.19	1
99.20	1
99.23	1
99.27	1
99.34	1
99.35	1
99.36	1
99.38	3
99.39	1
99.47	3
99.49	3
99.50	2
99.52	3
99.53	2
99.54	1
99.64	1
99.72	2
99.83	1
99.87	1
99.96	1
100.00	12

dtype: int64

School Type

Primary 67570

Secondary 67682

dtype: int64

Conclusion

Overall, we have shown a clear understanding of python and an extensive use of multiple libraries, including pandas, matplotlib, texttable, numpy, and many more. We have implemented all of the basic requirements and all of the extensions except one, stating in this jupyter notebook our decisions and our interpretations of the requirements, before the cell containing the appropriate information.

We have ensured that our functions are as reproduceable and reusable as possible, which is proved with the 2nd hard extension, where the analysing of a new data set did not require any new functions, simply a new array of the new data. Therefore, we are confident that our functions can be used with any data set and are very easy to use. Similarly, the functions that create plots can be used with almost anything, as all they require are arrays of values and axes names, making them very reusable in different projects.

Apart from the few lines of code that used pandas (which were modified from the lecture notes), all of the code was written by us, with the help of the library definitions and documentation on the internet (e.g. matplotlib.org).