main

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1 Making Better Clothing Size Recommendations

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1.1 Summary of Findings

1.1.1 Introduction

As we transition into a world driven by e-commerce, retail business such as the clothing industry face signifcant issues with customers returning products for a variety of issues which especially includes wrong product sizes. This python notebook works to mitigate the issue of customers returning products due to improper fit by leveraging lots of customer data in order to make better clothing size recommendations through machine learning.

In this project, I worked with a clothing dataset from RentTheRunway extracted by the following research team cited below:

Decomposing fit semantics for product size recommendation in metric spaces
Rishabh Misra, Mengting Wan, Julian McAuley RecSys, 2018

From this dataset which contained about 192,544 raw customer information, I was able to process and extract features which would be later used to create models in order to make size recommendations.

1.1.2 Cleaning and EDA

Since I was working with a raw dataset extracted by another research team, it was necessary to create a method in order to process the data. This process included standardizing columns such as: weight, height, bust size, age and converting the column datatypes to what made the most sense. Finally, the cleaning process included removing entries which had missing features in which I was left with 146,142 entries which was sufficient in creating a model. One thing to keep in mind is that the clothing category is greatly skewed towards dresses and gowns due to the nature of the clothing website RentTheRunway, but serves as a good proof of concept to market to other clothing companies.

The Exploratory Data Analysis included looking into the basic statistics of the dataset, analyzing the review_text column through a word cloud, and looking into the numerical correlation of features with the product size. Through this analysis, I was able to evaluate the best course of action in order to create an optimal model, and better understand the dataset.

1.1.3 Model Selection

In my baseline model, I utilized numerical features which included: weight, height, age, and bust size. Additionally, I included categorical features which required one-hot-encoding such as: bust cup, body type, and category. I experimented with various regression algorithms such as Linear Regression, and Decision Tree Regressor in which I recieved the best performance with Decision Tree Regressor of max_depth 10 with a training RSME of 3.70, and test RMSE of 3.88. The test size that I utilized in both the baseline model and final model is 0.2 which means 80% of the data is utilized for the training set, 20% of the data is utilized in the test set.

I chose to use the RMSE as the metric in order to evaluate the model performance because it calculates the total error across the sizes of the collective datapoints. I chose to use RMSE over MSE because it doesn't put more weight on penalizing larger errors which I deemed was not very significant due to the likelyhood that the product would be returned. Across varying categories (some had very little samples sizes), there was a difference in RSME which affected the model performance overall. The RSME tells us the variability of the size differences between the datapoints, and the significance of this number depends on the size spread of that specific category. Ideally, the RMSE is low, but in many clothing category, the size variability might not make a significant difference in customer satisfaction. In several categories, the model made very good size recommendations close to the sizes that the customer would've ordered and served as a great proof of concept for pursuing another final model.

In my final model, I conducted a grid search with varying hyperparameters and ended up choosing the Random Forest Regressor of max_depth: 18, n_estimators: 15, and max_features: auto. The final model performance was better than the baseline and had a train RSME of 2.77, and test RSME of 3.67. Although the final model performance only slightly better than the baseline model, upon further investigation, it seems that the model has trouble recommending sizes for clothing categories which lack sufficient sample sizes.

1.1.4 Results & Outcome

In conclusion, this technical analysis indicates that it's possible to create a model which could decently recommend clothing sizes for customers. The significance of this finding is that we're able to mitigate the amount of clothing returns and reduce carbon emission due to shipping & packaging while minimizing profit loss.

Although this project can decently recommend clothing sizes, it could be further improved by looking into adding more sample sizes for specific categories, exploring different recommender systems based on similar users (jaccard similarity, cosine similarity), adding features such as: gender, more specific body measurements, or utilizing neural networks.

Finally, the next possible steps for utilizing this clothing size recommender tool is to market this technology to other clothing companies, creating an simple User Interface, implement the model as a python application, and making improvements to the data pipeline to improve sample sizes across all clothing categories. Although this model can be deployed immediately, I would recommend making several improvements to the model performance, and implementing this feature to a small subset of customers to gain insights. Additionally, this dataset allows for further project exploration such as sentiment analysis, product recommendations, and web development.

2 Code

2.0.1 Library Imports

[1]:
```
import pandas as pd
import numpy as np
import gzip

import seaborn as sns
import matplotlib.pyplot as plt

from sklearn.tree import DecisionTreeRegressor
from sklearn.ensemble import RandomForestRegressor
from sklearn.compose import ColumnTransformer
from sklearn.model_selection import GridSearchCV
from sklearn.metrics import mean_squared_error
from sklearn.preprocessing import OneHotEncoder
from sklearn.preprocessing import FunctionTransformer
from sklearn.model_selection import train_test_split
from sklearn.pipeline import Pipeline

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

2.0.2 Data Extraction

[2]:
```
def readJSON(path):
    null = None

    for l in gzip.open(path, 'rt'):
        yield eval(l)

data = list(readJSON("renttherunway_final_data.json.gz"))
data = pd.DataFrame(data)
```

[3]:
```
data.head()
```

[3]:

	fit	user_id	bust size	item_id	weight	rating	rented for	review_text	body type
0	fit	420272	34d	2260466	137lbs	10	vacation	An adorable romper! Belt and zipper were a lit…	hourglass
1	fit	273551	34b	153475	132lbs	10	other	I rented this dress for a photo shoot. The the…	straight & narrow
2	fit	360448	NaN	1063761	NaN	10	party	This hugged in all the right places! It was a …	NaN
3	fit	909926	34c	126335	135lbs	8	formal affair		
4	fit	151944	34b	616682	145lbs	10	wedding		

```
3  I rented this for my company's black tie award…              pear
4  I have always been petite in my upper body and…          athletic

                                    review_summary category height  size  \
0                              So many compliments!   romper  5' 8"    14
1                            I felt so glamourous!!!     gown  5' 6"    12
2  It was a great time to celebrate the (almost) …   sheath  5' 4"     4
3   Dress arrived on time and in perfect condition.     dress  5' 5"     8
4                     Was in love with this dress !!!     gown  5' 9"    12

   age         review_date
0   28      April 20, 2016
1   36       June 18, 2013
2  116   December 14, 2015
3   34   February 12, 2014
4   27  September 26, 2016
```

2.0.3 Cleaning and EDA

[4]:
```
def standardize_height(str_in):
    output = ""
    if "\'" in str_in:
        str_in = str_in.replace('"', "")
        str_in = str_in.split("\' ")
        str_in = int(str_in[0])*12 + int(str_in[1])

        output = str_in

    return output

def standardize_bust(str_in):
    return str_in[:2]

def standardize_cup(str_in):
    return str_in[2:]

def standardize_age(x):
    if x > 100 or x < 18 or x == "nan":
        return np.NaN
    else:
        return x

def clean_data(df):
    # Remove missing entries
    df = df.dropna()

    # Standardize numerical features
```

```
    df["bust cup"] = df["bust size"].apply(standardize_cup)
    df["bust size"] = df["bust size"].apply(standardize_bust)

    df["weight"] = df["weight"].str.replace("lbs", "").astype(float)

    df["height"] = df["height"].astype(str)
    df["height"] = df["height"].apply(standardize_height).replace("", np.NaN).
↪astype(float)

    # Specify datatype for columns
    df["fit"] = df["fit"].astype(str)
    df["user_id"] = df["user_id"].astype(str)
    df["bust size"] = df["bust size"].astype(int)
    df["item_id"] = df["item_id"].astype(int)
    df["weight"] = df["weight"].astype(float)
    df["rating"] = df["rating"].astype(int)
    df["rented for"] = df["rented for"].astype(str)
    df["review_text"] = df["review_text"].astype(str)
    df["body type"] = df["body type"].astype(str)
    df["review_summary"] = df["review_summary"].astype(str)
    df["category"] = df["category"].astype(str)
    df["height"] = df["height"].astype(float)
    df["size"] = df["size"].astype(float)
    df["age"] = df["age"].astype(int)

    # Standardize Age
    df["age"] = df["age"].apply(standardize_age)

    # Remove missing entries
    df = df.dropna()

    return df
```

[5]:
```
data.head()
```

[5]:

	fit	user_id	bust size	item_id	weight	rating	rented for	review_text	body type
0	fit	420272	34d	2260466	137lbs	10	vacation	An adorable romper! Belt and zipper were a lit…	hourglass
1	fit	273551	34b	153475	132lbs	10	other	I rented this dress for a photo shoot. The the…	straight & narrow
2	fit	360448	NaN	1063761	NaN	10	party	This hugged in all the right places! It was a …	NaN
3	fit	909926	34c	126335	135lbs	8	formal affair	I rented this for my company's black tie award…	pear
4	fit	151944	34b	616682	145lbs	10	wedding		

```
4  I have always been petite in my upper body and…          athletic

                                    review_summary category height  size  \
0                            So many compliments!   romper  5' 8"    14
1                          I felt so glamourous!!!     gown  5' 6"    12
2  It was a great time to celebrate the (almost) …   sheath  5' 4"     4
3   Dress arrived on time and in perfect condition.     dress  5' 5"     8
4                   Was in love with this dress !!!     gown  5' 9"    12

   age         review_date
0   28      April 20, 2016
1   36       June 18, 2013
2  116   December 14, 2015
3   34   February 12, 2014
4   27  September 26, 2016
```

[6]:
```
data.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 192544 entries, 0 to 192543
Data columns (total 15 columns):
 #   Column          Non-Null Count   Dtype
---  ------          --------------   -----
 0   fit             192544 non-null  object
 1   user_id         192544 non-null  object
 2   bust size       174133 non-null  object
 3   item_id         192544 non-null  object
 4   weight          162562 non-null  object
 5   rating          192462 non-null  object
 6   rented for      192534 non-null  object
 7   review_text     192544 non-null  object
 8   body type       177907 non-null  object
 9   review_summary  192544 non-null  object
 10  category        192544 non-null  object
 11  height          191867 non-null  object
 12  size            192544 non-null  int64
 13  age             191584 non-null  object
 14  review_date     192544 non-null  object
dtypes: int64(1), object(14)
memory usage: 22.0+ MB
```

[7]:
```
data.describe()
```

[7]:
```
                size
count  192544.000000
mean       12.245175
std         8.494877
min         0.000000
```

```
25%         8.000000
50%        12.000000
75%        16.000000
max        58.000000
```

[8]:
```
clothing = clean_data(data)
clothing.head()
```

[8]:
```
   fit user_id  bust size  item_id  weight  rating     rented for  \
0  fit  420272         34  2260466   137.0      10       vacation
1  fit  273551         34   153475   132.0      10          other
3  fit  909926         34   126335   135.0       8  formal affair
4  fit  151944         34   616682   145.0      10        wedding
5  fit  734848         32   364092   138.0       8           date

                                        review_text          body type  \
0  An adorable romper! Belt and zipper were a lit…          hourglass
1  I rented this dress for a photo shoot. The the…  straight & narrow
3  I rented this for my company's black tie award…               pear
4  I have always been petite in my upper body and…           athletic
5  Didn't actually wear it. It fit perfectly. The…           athletic

                                  review_summary category  height  size  \
0                            So many compliments!   romper    68.0  14.0
1                          I felt so glamourous!!!     gown    66.0  12.0
3  Dress arrived on time and in perfect condition.     dress    65.0   8.0
4                  Was in love with this dress !!!     gown    69.0  12.0
5                  Traditional with a touch a sass    dress    68.0   8.0

    age         review_date bust cup
0  28.0      April 20, 2016       d
1  36.0       June 18, 2013       b
3  34.0   February 12, 2014       c
4  27.0  September 26, 2016       b
5  45.0      April 30, 2016       b
```

[9]:
```
clothing.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 146142 entries, 0 to 192543
Data columns (total 16 columns):
 #   Column          Non-Null Count   Dtype
---  ------          --------------   -----
 0   fit             146142 non-null  object
 1   user_id         146142 non-null  object
 2   bust size       146142 non-null  int32
 3   item_id         146142 non-null  int32
 4   weight          146142 non-null  float64
```

```
 5   rating          146142 non-null  int32
 6   rented for      146142 non-null  object
 7   review_text     146142 non-null  object
 8   body type       146142 non-null  object
 9   review_summary  146142 non-null  object
 10  category        146142 non-null  object
 11  height          146142 non-null  float64
 12  size            146142 non-null  float64
 13  age             146142 non-null  float64
 14  review_date     146142 non-null  object
 15  bust cup        146142 non-null  object
dtypes: float64(4), int32(3), object(9)
memory usage: 17.3+ MB
```

[10]:
```
clothing.describe()
```

[10]:

	bust size	item_id	weight	rating	\
count	146142.000000	1.461420e+05	146142.000000	146142.000000	
mean	34.111768	1.052212e+06	137.219725	9.081551	
std	1.701768	8.092531e+05	21.540950	1.438089	
min	28.000000	1.233730e+05	50.000000	2.000000	
25%	32.000000	1.956130e+05	123.000000	8.000000	
50%	34.000000	9.618190e+05	135.000000	10.000000	
75%	36.000000	1.687082e+06	148.000000	10.000000	
max	48.000000	2.966087e+06	300.000000	10.000000	

	height	size	age
count	146142.000000	146142.000000	146142.000000
mean	65.263059	11.440975	34.093409
std	2.658955	7.826571	7.956848
min	54.000000	0.000000	18.000000
25%	63.000000	4.000000	29.000000
50%	65.000000	9.000000	32.000000
75%	67.000000	16.000000	37.000000
max	78.000000	58.000000	100.000000

[11]:
```
clothing.head()
```

[11]:

	fit	user_id	bust size	item_id	weight	rating	rented for	\
0	fit	420272	34	2260466	137.0	10	vacation	
1	fit	273551	34	153475	132.0	10	other	
3	fit	909926	34	126335	135.0	8	formal affair	
4	fit	151944	34	616682	145.0	10	wedding	
5	fit	734848	32	364092	138.0	8	date	

	review_text	body type	\
0	An adorable romper! Belt and zipper were a lit…	hourglass	
1	I rented this dress for a photo shoot. The the…	straight & narrow	

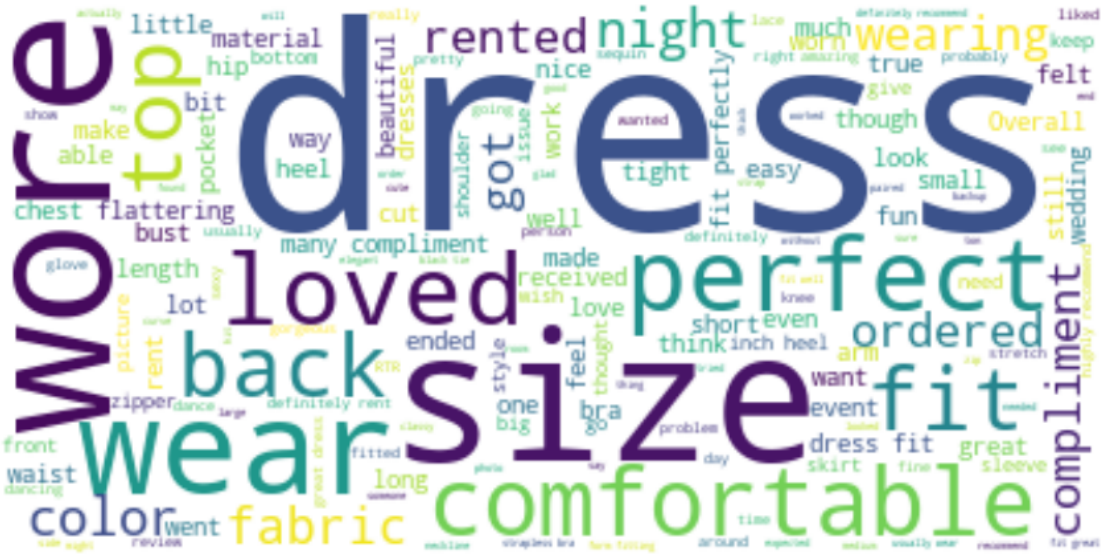
```
3  I rented this for my company's black tie award…              pear
4  I have always been petite in my upper body and…          athletic
5  Didn't actually wear it. It fit perfectly. The…          athletic

                                    review_summary category  height  size  \
0                                So many compliments!   romper    68.0  14.0
1                              I felt so glamourous!!!     gown    66.0  12.0
3  Dress arrived on time and in perfect condition.     dress    65.0   8.0
4                     Was in love with this dress !!!     gown    69.0  12.0
5                     Traditional with a touch a sass    dress    68.0   8.0

    age         review_date bust cup
0  28.0      April 20, 2016        d
1  36.0       June 18, 2013        b
3  34.0   February 12, 2014        c
4  27.0  September 26, 2016        b
5  45.0      April 30, 2016        b
```

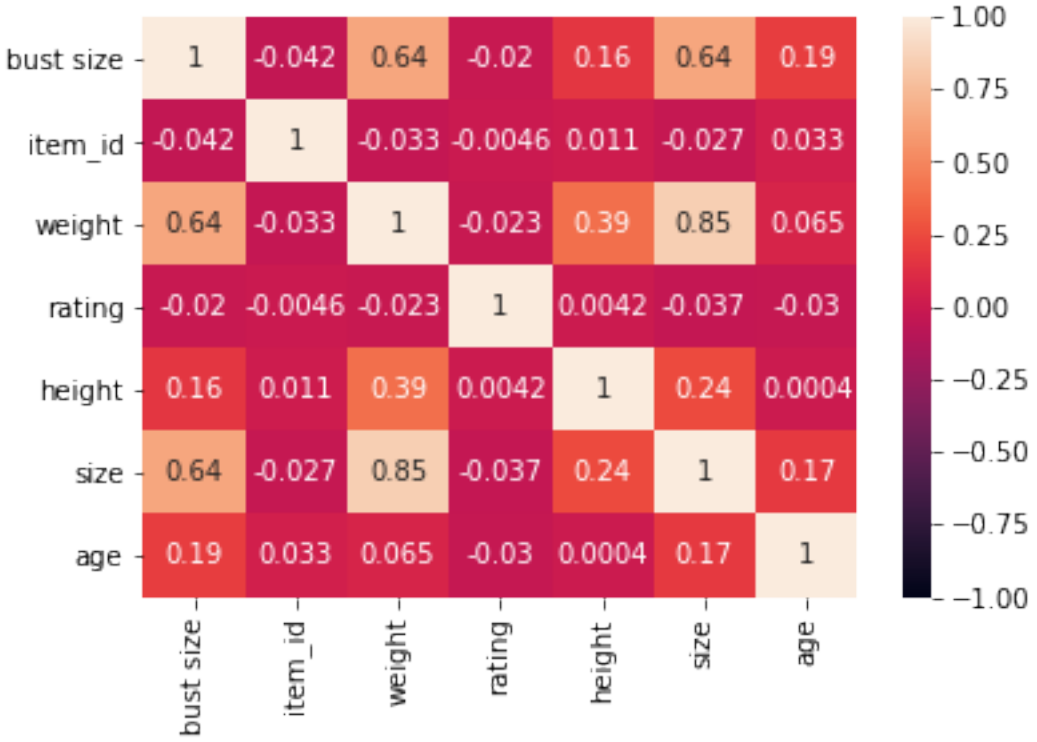
[12]:
```
from wordcloud import WordCloud
from wordcloud import ImageColorGenerator
from wordcloud import STOPWORDS

text = " ".join(i for i in clothing["review_text"])
stopwords = set(STOPWORDS)
wordcloud = WordCloud(stopwords=stopwords, background_color="white").
 ↪generate(text)
plt.figure(figsize=(15,10))
plt.imshow(wordcloud, interpolation='bilinear')
plt.axis("off")
plt.savefig('WordCloud.png')
plt.show()
```



[13]:
```
# Observe features from correlation heat map according to the size column.
# We will experiment with bust size, weight, height, and age since they have a positive correlation with size.
sns.heatmap(clothing.corr(), vmin=-1, vmax=1, annot=True)
```

[13]: <AxesSubplot:>



2.0.4 Baseline Model

[14]:
```
X = clothing[['fit', 'user_id', "bust cup", 'bust size', 'item_id', 'weight',␣
 ↪'rating',
       'rented for', 'review_text', 'body type', 'review_summary', 'category',
       'height', 'age', 'review_date']]
y = clothing['size']

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2)
```

[15]:
```
performance_df = pd.DataFrame()
nothing_transformer = FunctionTransformer()
preproc = ColumnTransformer(
transformers = [
    ("nothing", nothing_transformer, ["weight", "height", "age", "bust size"]),
    ("onehot", OneHotEncoder(handle_unknown="ignore"), ["bust cup", "category",␣
 ↪"body type", "fit"])
])

# Search for the depth which provides the most optimal model performance based␣
 ↪on the test set
for depth_ in range(1, 15):
    pl = Pipeline([
        ('preprocessor', preproc),
        ('DecisionTreeClassifer', DecisionTreeRegressor(max_depth=depth_))
         ])

    pl.fit(X_train, y_train)

    train_rsme = mean_squared_error(pl.predict(X_train), y_train, squared=False)
    test_rsme = mean_squared_error(pl.predict(X_test), y_test, squared=False)

    output = {"Depth": depth_, "Train rsme": train_rsme, "Test rsme": test_rsme}

    performance_df = performance_df.append(output, ignore_index=True)

performance_df.iloc[performance_df["Test rsme"].idxmin()]
```

[15]:
```
Depth         10.000000
Train rsme     3.646213
Test rsme      3.841723
Name: 9, dtype: float64
```

3 Final Model

[16]:
```
preproc = ColumnTransformer(
transformers = [
    ("nothing", nothing_transformer, ["weight", "height", "age", "bust size"]),
    ("onehot", OneHotEncoder(handle_unknown="ignore"), ["bust cup", "category",␣
 ↪"body type", "fit"])
])
pl = Pipeline([
        ('preprocessor', preproc),
        ('clf',  RandomForestRegressor())
         ])
```

[17]:
```
hyperparameters = {
    'clf__max_depth': [12, 15, 18, 21, 24],
    'clf__n_estimators': [12, 15, 18],
    'clf__max_features': ['auto']
}

grids = GridSearchCV(pl, param_grid=hyperparameters, return_train_score=True,␣
 ↪scoring="neg_root_mean_squared_error")
grids.fit(X_train, y_train)
```

[17]:
```
GridSearchCV(estimator=Pipeline(steps=[('preprocessor',
ColumnTransformer(transformers=[('nothing',
FunctionTransformer(),
['weight',
'height',
                                                                    'age',
                                                                    'bust
'
'size']),
('onehot',
OneHotEncoder(handle_unknown='ignore'),
                                                                  ['bust
'
                                                                    'cup',
'category',
                                                                    'body
'
'type',
'fit'])])),
                                       ('clf', RandomForestRegressor())]),
             param_grid={'clf__max_depth': [12, 15, 18, 21, 24],
                         'clf__max_features': ['auto'],
                         'clf__n_estimators': [12, 15, 18]},
             return_train_score=True, scoring='neg_root_mean_squared_error')
```

[18]:
```
grids.score(X_train, y_train)
```

[18]:
```
-3.0064749220027487
```

[19]:
```
grids.score(X_test, y_test)
```

[19]:
```
-3.6289683965315134
```

[20]:
```
grids.best_params_
```

[20]:
```
{'clf__max_depth': 15, 'clf__max_features': 'auto', 'clf__n_estimators': 18}
```

[21]:
```
cat = X_test["category"].unique()
output = pd.DataFrame(columns=["category", "Train RSME", "Test RSME"])

for i in cat:
    y_train_pred = grids.predict(X_train[X_train["category"] == i])
    y_train_temp = y_train[X_train["category"] == i]

    y_test_pred = grids.predict(X_test[X_test["category"] == i])
    y_test_temp = y_test[X_test["category"] == i]

    temp_dict = {"category": i, "Train RSME": mean_squared_error(y_train_pred,␣
 ↪y_train_temp, squared=False), "Test RSME": mean_squared_error(y_test_pred,␣
 ↪y_test_temp, squared=False)}

    output = output.append(temp_dict, ignore_index=True)


output = output.merge(pd.DataFrame(clothing.groupby("category")["size"].min()).
 ↪rename(columns={"size": "Min Size"}).reset_index(), how="inner",␣
 ↪on="category")
output = output.merge(pd.DataFrame(clothing.groupby("category")["size"].max()).
 ↪rename(columns={"size": "Max Size"}).reset_index(), how="inner",␣
 ↪on="category")
output = output.merge(pd.DataFrame(clothing.groupby("category")["size"].
 ↪count()).rename(columns={"size": "Count"}).reset_index(), how="inner",␣
 ↪on="category")

output = output[["category", "Count", "Min Size", "Max Size", "Train RSME",␣
 ↪"Test RSME"]].rename(columns={"category": "Category", "Train RSME": "Train␣
 ↪RMSE", "Test RSME": "Test RMSE"})
output
```

[21]:

	Category	Count	Min Size	Max Size	Train RSME	Test RSME
0	gown	33212	0.0	58.0	3.080774	3.801125
1	dress	70358	0.0	57.0	3.082926	3.573631

2	sheath	14669	1.0	57.0	2.967899	3.897418
3	mini	1414	1.0	24.0	2.546394	2.882818
4	cardigan	195	4.0	20.0	2.712809	4.19549
5	jumpsuit	4012	0.0	51.0	2.840596	3.388536
6	blazer	620	1.0	28.0	2.532217	2.709128
7	coat	769	1.0	35.0	2.705759	3.399124
8	shift	4036	1.0	57.0	2.951176	4.009476
9	top	3777	1.0	28.0	2.635176	3.196914
10	maxi	2596	0.0	57.0	2.834489	3.346189
11	sweater	919	1.0	26.0	2.536602	3.640677
12	trouser	48	1.0	24.0	2.776559	2.925273
13	romper	2443	1.0	28.0	2.65065	3.371058
14	jacket	1867	1.0	28.0	2.592564	3.091891
15	down	378	1.0	24.0	2.661729	2.837172
16	culottes	160	1.0	24.0	2.418877	3.015869
17	vest	218	1.0	26.0	2.670731	3.32424
18	skirt	1203	1.0	35.0	2.776271	3.33168
19	kaftan	13	4.0	20.0	1.86892	6.630798
20	sweatshirt	97	1.0	26.0	2.975146	4.426737
21	overalls	6	8.0	20.0	3.278829	6.056986
22	pants	322	1.0	28.0	2.654144	3.762232
23	blouse	489	1.0	28.0	2.506178	2.77934
24	shirtdress	563	1.0	35.0	2.478857	2.947445
25	shirt	216	1.0	26.0	2.61174	3.229956
26	combo	7	4.0	20.0	1.298293	3.289221
27	culotte	58	1.0	24.0	2.380754	3.158528
28	print	89	4.0	20.0	2.799374	2.472496
29	suit	108	1.0	20.0	2.479591	2.064538
30	bomber	102	1.0	26.0	2.703836	3.702373
31	midi	39	4.0	24.0	2.75818	1.836784
32	leggings	94	4.0	26.0	3.127275	2.913067
33	legging	80	4.0	20.0	2.720263	3.289932
34	trench	20	4.0	20.0	2.443718	2.391442
35	kimono	24	4.0	20.0	3.040946	5.080169
36	tunic	134	1.0	24.0	2.421831	3.129671
37	frock	164	1.0	28.0	2.787231	3.368688
38	pant	79	1.0	20.0	2.681738	2.815495
39	ballgown	12	16.0	54.0	2.943624	2.99628
40	knit	39	4.0	20.0	2.761422	1.491752
41	turtleneck	23	4.0	26.0	3.231843	3.80618
42	pullover	45	4.0	26.0	2.235526	3.249793
43	tank	141	1.0	28.0	2.938036	4.263066
44	duster	12	4.0	14.0	2.618407	2.318508
45	jeans	4	8.0	20.0	0.757108	6.46073
46	cami	12	1.0	20.0	2.996275	1.117999
47	tight	13	4.0	20.0	2.11316	4.325344
48	poncho	33	4.0	26.0	2.733884	6.580975

49	skirts	4	4.0	14.0	2.937375	2.654708
50	for	5	4.0	20.0	2.75869	4.499423
51	cape	68	1.0	24.0	3.075007	4.487362
52	peacoat	33	1.0	24.0	2.530224	5.47043
53	jogger	4	4.0	14.0	1.449229	5.215697
54	sweatershirt	3	8.0	14.0	0.986637	0.696368
55	skort	4	4.0	14.0	2.846877	0.70732
56	t-shirt	11	1.0	20.0	2.441018	0.554041
57	blouson	10	1.0	20.0	2.226435	4.072752

[22]:
```
import dataframe_image as dfi
dfi.export(output, 'dataframe.png')
```