



# Practice lab: Deep Learning for Content-Based Filtering

In this exercise, you will implement content-based filtering using a neural network to build a recommender system for movies.

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**NOTE:** To prevent errors from the autograder, you are not allowed to edit or delete non-graded cells in this lab. Please also refrain from adding any new cells. **Once you have passed this assignment** and want to experiment with any of the non-graded code, you may follow the instructions at the bottom of this notebook.



## 1 - Packages

We will use familiar packages, NumPy, TensorFlow and helpful routines from [scikit-learn](https://scikit-learn.org/stable/) (<https://scikit-learn.org/stable/>). We will also use [tabulate](https://pypi.org/project/tabulate/) (<https://pypi.org/project/tabulate/>) to neatly print tables and [Pandas](https://pandas.pydata.org/) (<https://pandas.pydata.org/>) to organize tabular data.

```
In [1]: import numpy as np
import numpy.ma as ma
import pandas as pd
import tensorflow as tf
from tensorflow import keras
from sklearn.preprocessing import StandardScaler, MinMaxScaler
from sklearn.model_selection import train_test_split
import tabulate
from recsysNN_utils import *
pd.set_option("display.precision", 1)
```



## 2 - Movie ratings dataset

The data set is derived from the [MovieLens ml-latest-small](https://grouplens.org/datasets/movielens/latest/) (<https://grouplens.org/datasets/movielens/latest/>) dataset.

[F. Maxwell Harper and Joseph A. Konstan. 2015. The MovieLens Datasets: History and Context. ACM Transactions on Interactive Intelligent Systems (TiiS) 5, 4: 19:1–19:19. <https://doi.org/10.1145/2827872> (<https://doi.org/10.1145/2827872>)]

The original dataset has roughly 9000 movies rated by 600 users with ratings on a scale of 0.5 to 5 in 0.5 step increments. The dataset has been reduced in size to focus on movies from the years since 2000 and popular genres. The reduced dataset has  $n_u = 397$  users,  $n_m = 847$  movies and 25521 ratings. For each movie, the dataset provides a movie title, release date, and one or more genres. For example "Toy Story 3" was released in 2010 and has several genres: "Adventure|Animation|Children|Comedy|Fantasy". This dataset contains little information about users other than their ratings. This dataset is used to create training vectors for the neural networks described below. Let's learn a bit more about this data set. The table below shows the top 10 movies ranked by the number of ratings. These movies also happen to have high average ratings. How many of these movies have you watched?

```
In [2]: top10_df = pd.read_csv("./data/content_top10_df.csv")
bygenre_df = pd.read_csv("./data/content_bygenre_df.csv")
top10_df
```

Out[2]:

	movie id	num ratings	ave rating	title	genres
0	4993	198	4.1	Lord of the Rings: The Fellowship of the Ring,...	Adventure Fantasy
1	5952	188	4.0	Lord of the Rings: The Two Towers, The	Adventure Fantasy
2	7153	185	4.1	Lord of the Rings: The Return of the King, The	Action Adventure Drama Fantasy
3	4306	170	3.9	Shrek	Adventure Animation Children Comedy Fantasy Ro...
4	58559	149	4.2	Dark Knight, The	Action Crime Drama
5	6539	149	3.8	Pirates of the Caribbean: The Curse of the Bla...	Action Adventure Comedy Fantasy
6	79132	143	4.1	Inception	Action Crime Drama Mystery Sci-Fi Thriller
7	6377	141	4.0	Finding Nemo	Adventure Animation Children Comedy
8	4886	132	3.9	Monsters, Inc.	Adventure Animation Children Comedy Fantasy
9	7361	131	4.2	Eternal Sunshine of the Spotless Mind	Drama Romance Sci-Fi

The next table shows information sorted by genre. The number of ratings per genre vary substantially. Note that a movie may have multiple genre's so the sum of the ratings below is larger than the number of original ratings.

In [3]: bygenre\_df

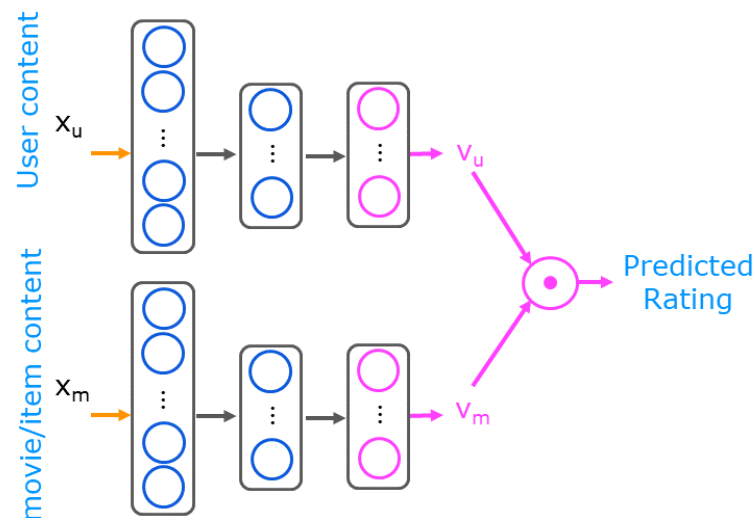
Out[3]:

	genre	num movies	ave rating/genre	ratings per genre
0	Action	321	3.4	10377
1	Adventure	234	3.4	8785
2	Animation	76	3.6	2588
3	Children	69	3.4	2472
4	Comedy	326	3.4	8911
5	Crime	139	3.5	4671
6	Documentary	13	3.8	280
7	Drama	342	3.6	10201
8	Fantasy	124	3.4	4468
9	Horror	56	3.2	1345
10	Mystery	68	3.6	2497
11	Romance	151	3.4	4468
12	Sci-Fi	174	3.4	5894
13	Thriller	245	3.4	7659

### 3 - Content-based filtering with a neural network

In the collaborative filtering lab, you generated two vectors, a user vector and an item/movie vector whose dot product would predict a rating. The vectors were derived solely from the ratings.

Content-based filtering also generates a user and movie feature vector but recognizes there may be other information available about the user and/or movie that may improve the prediction. The additional information is provided to a neural network which then generates the user and movie vector as shown below.



#### 3.1 Training Data

The movie content provided to the network is a combination of the original data and some 'engineered features'. Recall the feature engineering discussion and lab from Course 1, Week 2, lab 4. The original features are the year the movie was released and the movie's genre's presented as a one-hot vector. There are 14 genres. The engineered feature is an average rating derived from the user ratings.

The user content is composed of engineered features. A per genre average rating is computed per user. Additionally, a user id, rating count and rating average are available but not included in the training or prediction content. They are carried with the data set because they are useful in interpreting data.

The training set consists of all the ratings made by the users in the data set. Some ratings are repeated to boost the number of training examples of underrepresented genre's. The training set is split into two arrays with the same number of entries, a user array and a movie/item array.

Below, let's load and display some of the data.

```
In [4]: # Load Data, set configuration variables
item_train, user_train, y_train, item_features, user_features, item_vecs, movie_dict, user_to_genre = load_data()

num_user_features = user_train.shape[1] - 3 # remove userid, rating count and ave rating during training
num_item_features = item_train.shape[1] - 1 # remove movie id at train time
uvs = 3 # user genre vector start
ivs = 3 # item genre vector start
u_s = 3 # start of columns to use in training, user
i_s = 1 # start of columns to use in training, items
print(f"Number of training vectors: {len(item_train)}")
```

Number of training vectors: 50884

Let's look at the first few entries in the user training array.

```
In [5]: pprint_train(user_train, user_features, uvs, u_s, maxcount=5)
```

```
Out[5]:
```

	[user id]	[rating count]	[rating ave]	Act ion	Adve nture	Anim ation	Chil dren	Com edy	Crime	Docum entary	Drama	Fan tasy	Hor ror	Mys tery	Ro an
	2	22	4.0	4.0	4.2	0.0	0.0	4.0	4.1	4.0	4.0	0.0	3.0	4.0	0.
	2	22	4.0	4.0	4.2	0.0	0.0	4.0	4.1	4.0	4.0	0.0	3.0	4.0	0.
	2	22	4.0	4.0	4.2	0.0	0.0	4.0	4.1	4.0	4.0	0.0	3.0	4.0	0.
	2	22	4.0	4.0	4.2	0.0	0.0	4.0	4.1	4.0	4.0	0.0	3.0	4.0	0.
	2	22	4.0	4.0	4.2	0.0	0.0	4.0	4.1	4.0	4.0	0.0	3.0	4.0	0.

Some of the user and item/movie features are not used in training. In the table above, the features in brackets "[]" such as the "user id", "rating count" and "rating ave" are not included when the model is trained and used. Above you can see the per genre rating average for user 2. Zero entries are genre's which the user had not rated. The user vector is the same for all the movies rated by a user.

Let's look at the first few entries of the movie/item array.

```
In [6]: pprint_train(item_train, item_features, ivs, i_s, maxcount=5, user=False)
```

```
Out[6]:
```

	[movie id]	year	ave rating	Act ion	Adve nture	Anim ation	Chil dren	Com edy	Crime	Docum entary	Drama	Fan tasy	Hor ror	Mys tery	Ror anc
	6874	2003	4.0	1	0	0	0	0	1	0	0	0	0	0	0
	8798	2004	3.8	1	0	0	0	0	1	0	1	0	0	0	0
	46970	2006	3.2	1	0	0	0	1	0	0	0	0	0	0	0
	48516	2006	4.3	0	0	0	0	0	1	0	1	0	0	0	0
	58559	2008	4.2	1	0	0	0	0	1	0	1	0	0	0	0

Above, the movie array contains the year the film was released, the average rating and an indicator for each potential genre. The indicator is one for each genre that applies to the movie. The movie id is not used in training but is useful when interpreting the data.

```
In [7]: print(f"y_train[:5]: {y_train[:5]}")  
y_train[:5]: [4.  3.5 4.  4.  4.5]
```

The target,  $y$ , is the movie rating given by the user.

Above, we can see that movie 6874 is an Action/Crime/Thriller movie released in 2003. User 2 rates action movies as 3.9 on average. MovieLens users gave the movie an average rating of 4. 'y' is 4 indicating user 2 rated movie 6874 as a 4 as well. A single training example consists of a row from both the user and item arrays and a rating from  $y\_train$ .

## 3.2 Preparing the training data

Recall in Course 1, Week 2, you explored feature scaling as a means of improving convergence. We'll scale the input features using the [scikit learn StandardScaler](https://scikit-learn.org/stable/modules/generated/sklearn.preprocessing.StandardScaler.html) (<https://scikit-learn.org/stable/modules/generated/sklearn.preprocessing.StandardScaler.html>). This was used in Course 1, Week 2, Lab 5. Below, the `inverse_transform` is also shown to produce the original inputs. We'll scale the target ratings using a Min Max Scaler which scales the target to be between -1 and 1. [scikit learn MinMaxScaler](https://scikit-learn.org/stable/modules/generated/sklearn.preprocessing.MinMaxScaler.html) (<https://scikit-learn.org/stable/modules/generated/sklearn.preprocessing.MinMaxScaler.html>).

```
In [8]: # scale training data
item_train_unscaled = item_train
user_train_unscaled = user_train
y_train_unscaled    = y_train

scalerItem = StandardScaler()
scalerItem.fit(item_train)
item_train = scalerItem.transform(item_train)

scalerUser = StandardScaler()
scalerUser.fit(user_train)
user_train = scalerUser.transform(user_train)

scalerTarget = MinMaxScaler((-1, 1))
scalerTarget.fit(y_train.reshape(-1, 1))
y_train = scalerTarget.transform(y_train.reshape(-1, 1))
#ynorm_test = scalerTarget.transform(y_test.reshape(-1, 1))

print(np.allclose(item_train_unscaled, scalerItem.inverse_transform(item_train)))
print(np.allclose(user_train_unscaled, scalerUser.inverse_transform(user_train)))

True
True
```

To allow us to evaluate the results, we will split the data into training and test sets as was discussed in Course 2, Week 3. Here we will use [sklearn train\\_test\\_split](https://scikit-learn.org/stable/modules/generated/sklearn.model_selection.train_test_split.html) ([https://scikit-learn.org/stable/modules/generated/sklearn.model\\_selection.train\\_test\\_split.html](https://scikit-learn.org/stable/modules/generated/sklearn.model_selection.train_test_split.html)) to split and shuffle the data. Note that setting the initial random state to the same value ensures item, user, and y are shuffled identically.

```
In [9]: item_train, item_test = train_test_split(item_train, train_size=0.80, shuffle=
True, random_state=1)
user_train, user_test = train_test_split(user_train, train_size=0.80, shuffle=
True, random_state=1)
y_train, y_test = train_test_split(y_train, train_size=0.80, shuffle=
True, random_state=1)
print(f"movie/item training data shape: {item_train.shape}")
print(f"movie/item test data shape: {item_test.shape}")

movie/item training data shape: (40707, 17)
movie/item test data shape: (10177, 17)
```

The scaled, shuffled data now has a mean of zero.

```
In [10]: pprint_train(user_train, user_features, uvs, u_s, maxcount=5)
```

```
Out[10]:
```

[user id]	[rating count]	[rating ave]	Act ion	Adve nture	Anim ation	Chil dren	Com edy	Crime	Docum entary	Drama	Fan tasy	Hor ror	Mys tery	Rc an
1	0	-1.0	-0.8	-0.7	0.1	-0.0	-1.2	-0.4	0.6	-0.5	-0.5	-0.1	-0.6	-0
0	1	-0.7	-0.5	-0.7	-0.1	-0.2	-0.6	-0.2	0.7	-0.5	-0.8	0.1	-0.0	-0
-1	-1	-0.2	0.3	-0.4	0.4	0.5	1.0	0.6	-1.2	-0.3	-0.6	-2.3	-0.1	0.
0	-1	0.6	0.5	0.5	0.2	0.6	-0.1	0.5	-1.2	0.9	1.2	-2.3	-0.1	0.
-1	0	0.7	0.6	0.5	0.3	0.5	0.4	0.6	1.0	0.6	0.3	0.8	0.8	0.

## 4 - Neural Network for content-based filtering

Now, let's construct a neural network as described in the figure above. It will have two networks that are combined by a dot product. You will construct the two networks. In this example, they will be identical. Note that these networks do not need to be the same. If the user content was substantially larger than the movie content, you might elect to increase the complexity of the user network relative to the movie network. In this case, the content is similar, so the networks are the same.

### Exercise 1

- Use a Keras sequential model
  - The first layer is a dense layer with 256 units and a relu activation.
  - The second layer is a dense layer with 128 units and a relu activation.
  - The third layer is a dense layer with `num_outputs` units and a linear or no activation.

The remainder of the network will be provided. The provided code does not use the Keras sequential model but instead uses the Keras [functional api](https://keras.io/guides/functional_api/) ([https://keras.io/guides/functional\\_api/](https://keras.io/guides/functional_api/)). This format allows for more flexibility in how components are interconnected.



```

In [11]: # GRADED_CELL
# UNQ_C1

num_outputs = 32
tf.random.set_seed(1)
user_NN = tf.keras.models.Sequential([
    ### START CODE HERE ###
    tf.keras.layers.Dense(256, activation='relu'),
    tf.keras.layers.Dense(128, activation='relu'),
    tf.keras.layers.Dense(num_outputs, activation='linear')
    ### END CODE HERE ###
])

item_NN = tf.keras.models.Sequential([
    ### START CODE HERE ###
    tf.keras.layers.Dense(256, activation='relu'),
    tf.keras.layers.Dense(128, activation='relu'),
    tf.keras.layers.Dense(num_outputs, activation='linear')
    ### END CODE HERE ###
])

# create the user input and point to the base network
input_user = tf.keras.layers.Input(shape=(num_user_features))
vu = user_NN(input_user)
vu = tf.linalg.l2_normalize(vu, axis=1)

# create the item input and point to the base network
input_item = tf.keras.layers.Input(shape=(num_item_features))
vm = item_NN(input_item)
vm = tf.linalg.l2_normalize(vm, axis=1)

# compute the dot product of the two vectors vu and vm
output = tf.keras.layers.Dot(axes=1)([vu, vm])

# specify the inputs and output of the model
model = tf.keras.Model([input_user, input_item], output)

model.summary()

```

Model: "model"

Layer (type)	Output Shape	Param #	Connected to
=====			
input_1 (InputLayer)	[(None, 14)]	0	
=====			
input_2 (InputLayer)	[(None, 16)]	0	
=====			
sequential (Sequential) [0]	(None, 32)	40864	input_1[0]
=====			
sequential_1 (Sequential) [0]	(None, 32)	41376	input_2[0]
=====			
tf_op_layer_l2_normalize/Square [0][0]	[(None, 32)]	0	sequential [0][0]
=====			
tf_op_layer_l2_normalize_1/Squa [0][0]	[(None, 32)]	0	sequential_1 [0][0]
=====			
tf_op_layer_l2_normalize/Sum (T l2_normalize/Square[0]	[(None, 1)]	0	tf_op_layer_ l2_normalize/Square[0]
=====			
tf_op_layer_l2_normalize_1/Sum l2_normalize_1/Square	[(None, 1)]	0	tf_op_layer_ l2_normalize_1/Square
=====			
tf_op_layer_l2_normalize/Maximu l2_normalize/Sum[0][0]	[(None, 1)]	0	tf_op_layer_ l2_normalize/Sum[0][0]
=====			
tf_op_layer_l2_normalize/Rsqrt l2_normalize/Maximum[	[(None, 1)]	0	tf_op_layer_ l2_normalize/Maximum[
=====			
tf_op_layer_l2_normalize_1/Rsq l2_normalize_1/Maximu	[(None, 1)]	0	tf_op_layer_ l2_normalize_1/Maximu
=====			
tf_op_layer_l2_normalize (Tenso [0][0]	[(None, 32)]	0	sequential [0][0]
=====			
l2_normalize/Rsqrt[0]			tf_op_layer_ l2_normalize/Rsqrt[0]
=====			

tf_op_layer_l2_normalize_1 (Ten [(None, 32)] [0])[0]	0	sequential_1
l2_normalize_1/Rsqrt[		tf_op_layer_
dot (Dot)	(None, 1)	tf_op_layer_
l2_normalize[0][0]		tf_op_layer_
l2_normalize_1[0][0]		
=====		
=====		
Total params: 82,240		
Trainable params: 82,240		
Non-trainable params: 0		
=====		
=====		

```
In [12]: # Public tests
from public_tests import *
test_tower(user_NN)
test_tower(item_NN)

All tests passed!
All tests passed!
```

## Click for hints

We will use a mean squared error loss and an Adam optimizer.

```
In [13]: tf.random.set_seed(1)
cost_fn = tf.keras.losses.MeanSquaredError()
opt = keras.optimizers.Adam(learning_rate=0.01)
model.compile(optimizer=opt,
              loss=cost_fn)
```

```
In [14]: tf.random.set_seed(1)
         model.fit([user_train[:, u_s:], item_train[:, i_s:]], y_train, epochs=30)
```

Train on 40707 samples

Epoch 1/30

40707/40707 [=====] - 5s 127us/sample - loss: 0.1232

Epoch 2/30

40707/40707 [=====] - 5s 115us/sample - loss: 0.1146

Epoch 3/30

40707/40707 [=====] - 5s 116us/sample - loss: 0.1089

Epoch 4/30

40707/40707 [=====] - 5s 115us/sample - loss: 0.1039

Epoch 5/30

40707/40707 [=====] - 5s 115us/sample - loss: 0.1001

Epoch 6/30

40707/40707 [=====] - 5s 114us/sample - loss: 0.0973

Epoch 7/30

40707/40707 [=====] - 5s 115us/sample - loss: 0.0956

Epoch 8/30

40707/40707 [=====] - 5s 115us/sample - loss: 0.0935

Epoch 9/30

40707/40707 [=====] - 5s 115us/sample - loss: 0.0916

Epoch 10/30

40707/40707 [=====] - 5s 115us/sample - loss: 0.0897

Epoch 11/30

40707/40707 [=====] - 5s 115us/sample - loss: 0.0880

Epoch 12/30

40707/40707 [=====] - 5s 115us/sample - loss: 0.0865

Epoch 13/30

40707/40707 [=====] - 5s 114us/sample - loss: 0.0852

Epoch 14/30

40707/40707 [=====] - 5s 114us/sample - loss: 0.0839

Epoch 15/30

40707/40707 [=====] - 5s 115us/sample - loss: 0.0830

Epoch 16/30

40707/40707 [=====] - 5s 115us/sample - loss: 0.0815

Epoch 17/30

40707/40707 [=====] - 5s 115us/sample - loss: 0.0807

Epoch 18/30

40707/40707 [=====] - 5s 113us/sample - loss: 0.0796

Epoch 19/30

40707/40707 [=====] - 5s 114us/sample - loss: 0.0786

Epoch 20/30

40707/40707 [=====] - 5s 115us/sample - loss: 0.0776

Epoch 21/30

40707/40707 [=====] - 5s 115us/sample - loss: 0.0769

Epoch 22/30

40707/40707 [=====] - 5s 115us/sample - loss: 0.0761

Epoch 23/30

40707/40707 [=====] - 5s 114us/sample - loss: 0.0755

Epoch 24/30

40707/40707 [=====] - 5s 115us/sample - loss: 0.0746

Epoch 25/30

40707/40707 [=====] - 5s 115us/sample - loss: 0.0741

Epoch 26/30

40707/40707 [=====] - 5s 113us/sample - loss: 0.0733

Epoch 27/30

40707/40707 [=====] - 5s 115us/sample - loss: 0.0728

Epoch 28/30

40707/40707 [=====] - 5s 114us/sample - loss: 0.0723

```
Epoch 29/30  
40707/40707 [=====] - 5s 114us/sample - loss: 0.0717  
Epoch 30/30  
40707/40707 [=====] - 5s 115us/sample - loss: 0.0713
```

```
Out[14]: <tensorflow.python.keras.callbacks.History at 0x7fbe5ce32e50>
```

Evaluate the model to determine loss on the test data.

```
In [15]: model.evaluate([user_test[:, u_s:], item_test[:, i_s:]], y_test)  
10177/10177 [=====] - 0s 33us/sample - loss: 0.0815
```

```
Out[15]: 0.08146006993124337
```

It is comparable to the training loss indicating the model has not substantially overfit the training data.

## 5 - Predictions

Below, you'll use your model to make predictions in a number of circumstances.

### 5.1 - Predictions for a new user

First, we'll create a new user and have the model suggest movies for that user. After you have tried this on the example user content, feel free to change the user content to match your own preferences and see what the model suggests. Note that ratings are between 0.5 and 5.0, inclusive, in half-step increments.

```
In [16]: new_user_id = 5000
new_rating_ave = 0.0
new_action = 0.0
new_adventure = 5.0
new_animation = 0.0
new_childrens = 0.0
new_comedy = 0.0
new_crime = 0.0
new_documentary = 0.0
new_drama = 0.0
new_fantasy = 5.0
new_horror = 0.0
new_mystery = 0.0
new_romance = 0.0
new_scifi = 0.0
new_thriller = 0.0
new_rating_count = 3

user_vec = np.array([[new_user_id, new_rating_count, new_rating_ave,
                        new_action, new_adventure, new_animation, new_childrens,
                        new_comedy, new_crime, new_documentary,
                        new_drama, new_fantasy, new_horror, new_mystery,
                        new_romance, new_scifi, new_thriller]])
```

The new user enjoys movies from the adventure, fantasy genres. Let's find the top-rated movies for the new user.

Below, we'll use a set of movie/item vectors, `item_vecs` that have a vector for each movie in the training/test set. This is matched with the new user vector above and the scaled vectors are used to predict ratings for all the movies.

```

In [17]: # generate and replicate the user vector to match the number movies in the data set.
user_vecs = gen_user_vecs(user_vec, len(item_vecs))

# scale our user and item vectors
suser_vecs = scalerUser.transform(user_vecs)
sitem_vecs = scalerItem.transform(item_vecs)

# make a prediction
y_p = model.predict([suser_vecs[:, u_s:], sitem_vecs[:, i_s:]])

# unscale y prediction
y_pu = scalerTarget.inverse_transform(y_p)

# sort the results, highest prediction first
sorted_index = np.argsort(-y_pu, axis=0).reshape(-1).tolist() #negate to get largest rating first
sorted_ypu = y_pu[sorted_index]
sorted_items = item_vecs[sorted_index] #using unscaled vectors for display

print_pred_movies(sorted_ypu, sorted_items, movie_dict, maxcount = 10)

```

Out[17]:

y_p	movie id	rating ave	title	genres
4.5	98809	3.8	Hobbit: An Unexpected Journey, The (2012)	Adventure Fantasy
4.4	8368	3.9	Harry Potter and the Prisoner of Azkaban (2004)	Adventure Fantasy
4.4	54001	3.9	Harry Potter and the Order of the Phoenix (2007)	Adventure Drama Fantasy
4.3	40815	3.8	Harry Potter and the Goblet of Fire (2005)	Adventure Fantasy Thriller
4.3	106489	3.6	Hobbit: The Desolation of Smaug, The (2013)	Adventure Fantasy
4.3	81834	4	Harry Potter and the Deathly Hallows: Part 1 (2010)	Action Adventure Fantasy
4.3	59387	4	Fall, The (2006)	Adventure Drama Fantasy
4.3	5952	4	Lord of the Rings: The Two Towers, The (2002)	Adventure Fantasy
4.3	5816	3.6	Harry Potter and the Chamber of Secrets (2002)	Adventure Fantasy
4.3	54259	3.6	Stardust (2007)	Adventure Comedy Fantasy Romance

## 5.2 - Predictions for an existing user.

Let's look at the predictions for "user 2", one of the users in the data set. We can compare the predicted ratings with the model's ratings.



```
In [18]: uid = 2
# form a set of user vectors. This is the same vector, transformed and repeated.
user_vecs, y_vecs = get_user_vecs(uid, user_train_unscaled, item_vecs, user_to_genre)

# scale our user and item vectors
suser_vecs = scalerUser.transform(user_vecs)
sitem_vecs = scalerItem.transform(item_vecs)

# make a prediction
y_p = model.predict([suser_vecs[:, u_s:], sitem_vecs[:, i_s:]])

# unscale y prediction
y_pu = scalerTarget.inverse_transform(y_p)

# sort the results, highest prediction first
sorted_index = np.argsort(-y_pu,axis=0).reshape(-1).tolist() #negate to get largest rating first
sorted_y pu    = y_pu[sorted_index]
sorted_items   = item_vecs[sorted_index] #using unscaled vectors for display
sorted_user    = user_vecs[sorted_index]
sorted_y       = y_vecs[sorted_index]

#print sorted predictions for movies rated by the user
print_existing_user(sorted_y pu, sorted_y.reshape(-1,1), sorted_user, sorted_items, ivs, uvs, movie_dict, maxcount = 50)
```

Out[18]:

y_p	y	user	user genre ave	movie rating ave	movie id	title	genres
4.5	5.0	2	[4.0]	4.3	80906	Inside Job (2010)	Documentary
4.2	3.5	2	[4.0,4.0]	3.9	99114	Django Unchained (2012)	Action Drama
4.1	4.5	2	[4.0,4.0]	4.1	68157	Inglourious Basterds (2009)	Action Drama
4.1	3.5	2	[4.0,3.9,3.9]	3.9	115713	Ex Machina (2015)	Drama Sci-Fi Thriller
4.0	4.0	2	[4.0,4.1,4.0,4.0,3.9,3.9]	4.1	79132	Inception (2010)	Action Crime Drama Mystery Sci-Fi Thriller
4.0	4.0	2	[4.1,4.0,3.9]	4.3	48516	Departed, The (2006)	Crime Drama Thriller
4.0	4.5	2	[4.0,4.1,4.0]	4.2	58559	Dark Knight, The (2008)	Action Crime Drama
4.0	4.0	2	[4.0,4.1,3.9]	4.0	6874	Kill Bill: Vol. 1 (2003)	Action Crime Thriller
4.0	3.5	2	[4.0,4.1,4.0,3.9]	3.8	8798	Collateral (2004)	Action Crime Drama Thriller
3.9	5.0	2	[4.0,4.1,4.0]	3.9	106782	Wolf of Wall Street, The (2013)	Comedy Crime Drama
3.9	3.5	2	[4.0,4.2,4.1]	4.0	91529	Dark Knight Rises, The (2012)	Action Adventure Crime
3.9	4.0	2	[4.0,4.0,3.9]	4.0	74458	Shutter Island (2010)	Drama Mystery Thriller
3.9	4.5	2	[4.1,4.0,3.9]	4.0	80489	Town, The (2010)	Crime Drama Thriller
3.8	4.0	2	[4.0]	4.0	112552	Whiplash (2014)	Drama
3.8	3.0	2	[3.9]	4.0	109487	Interstellar (2014)	Sci-Fi
3.8	5.0	2	[4.0]	3.7	89774	Warrior (2011)	Drama
3.7	3.0	2	[4.0,4.0,3.0]	3.9	71535	Zombieland (2009)	Action Comedy Horror
3.7	5.0	2	[4.0,4.2,3.9,3.9]	3.8	122882	Mad Max: Fury Road (2015)	Action Adventure Sci-Fi Thriller
3.5	5.0	2	[4.0]	3.6	60756	Step Brothers (2008)	Comedy

y_p	y	user	user genre ave	movie rating ave	movie id	title	genres
3.5	2.5	2	[4.0,3.9]	3.5	91658	Girl with the Dragon Tattoo, The (2011)	Drama Thriller
3.1	3.0	2	[4.0,4.0]	4.0	77455	Exit Through the Gift Shop (2010)	Comedy Documentary
3.1	4.0	2	[4.0,4.0]	3.2	46970	Talladega Nights: The Ballad of Ricky Bobby (2006)	Action Comedy

The model prediction is generally within 1 of the actual rating though it is not a very accurate predictor of how a user rates specific movies. This is especially true if the user rating is significantly different than the user's genre average. You can vary the user id above to try different users. Not all user id's were used in the training set.

## 5.3 - Finding Similar Items

The neural network above produces two feature vectors, a user feature vector  $v_u$ , and a movie feature vector,  $v_m$ . These are 32 entry vectors whose values are difficult to interpret. However, similar items will have similar vectors. This information can be used to make recommendations. For example, if a user has rated "Toy Story 3" highly, one could recommend similar movies by selecting movies with similar movie feature vectors.

A similarity measure is the squared distance between the two vectors  $\mathbf{v}_m^{(k)}$  and  $\mathbf{v}_m^{(i)}$  :

$$\left\| \mathbf{v}_m^{(k)} - \mathbf{v}_m^{(i)} \right\|^2 = \sum_{l=1}^n (v_{m_l}^{(k)} - v_{m_l}^{(i)})^2 \quad (1)$$

## Exercise 2

Write a function to compute the square distance.

```
In [22]: # GRADED_FUNCTION: sq_dist
# UNQ_C2
def sq_dist(a,b):
    """
    Returns the squared distance between two vectors
    Args:
        a (ndarray (n,)): vector with n features
        b (ndarray (n,)): vector with n features
    Returns:
        d (float) : distance
    """
    ### START CODE HERE ###
    d = np.linalg.norm(a-b,2)**2
    ### END CODE HERE ###
    return d
```

```
In [23]: a1 = np.array([1.0, 2.0, 3.0]); b1 = np.array([1.0, 2.0, 3.0])
a2 = np.array([1.1, 2.1, 3.1]); b2 = np.array([1.0, 2.0, 3.0])
a3 = np.array([0, 1, 0]); b3 = np.array([1, 0, 0])
print(f"squared distance between a1 and b1: {sq_dist(a1, b1):0.3f}")
print(f"squared distance between a2 and b2: {sq_dist(a2, b2):0.3f}")
print(f"squared distance between a3 and b3: {sq_dist(a3, b3):0.3f}")

squared distance between a1 and b1: 0.000
squared distance between a2 and b2: 0.030
squared distance between a3 and b3: 2.000
```

### Expected Output:

squared distance between a1 and b1: 0.000  
squared distance between a2 and b2: 0.030  
squared distance between a3 and b3: 2.000

```
In [24]: # Public tests
test_sq_dist(sq_dist)
```

All tests passed!

### Click for hints

A matrix of distances between movies can be computed once when the model is trained and then reused for new recommendations without retraining. The first step, once a model is trained, is to obtain the movie feature vector,  $v_m$ , for each of the movies. To do this, we will use the trained `item_NN` and build a small model to allow us to run the movie vectors through it to generate  $v_m$ .

```
In [25]: input_item_m = tf.keras.layers.Input(shape=(num_item_features))    # input Layer
vm_m = item_NN(input_item_m)                                              # use the trained item_NN
vm_m = tf.linalg.l2_normalize(vm_m, axis=1)                               # incorporate normalization as was done in the original model
model_m = tf.keras.Model(input_item_m, vm_m)
model_m.summary()
```

Model: "model\_1"

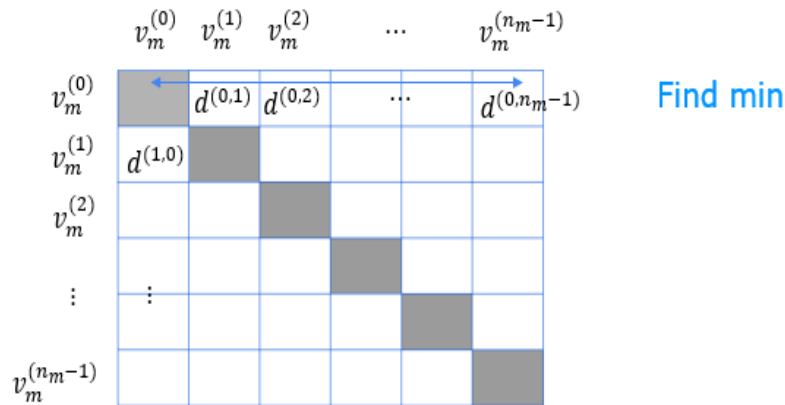
Layer (type)	Output Shape	Param #	Connected to
=====			
input_3 (InputLayer)	[(None, 16)]	0	
=====			
sequential_1 (Sequential)	(None, 32)	41376	input_3[0]
=====			
tf_op_layer_l2_normalize_2/Square	[(None, 32)]	0	sequential_1[1][0]
=====			
tf_op_layer_l2_normalize_2/Sum	[(None, 1)]	0	tf_op_layer_l2_normalize_2/Square
=====			
tf_op_layer_l2_normalize_2/Maximum	[(None, 1)]	0	tf_op_layer_l2_normalize_2/Sum[0]
=====			
tf_op_layer_l2_normalize_2/Rsqrt	[(None, 1)]	0	tf_op_layer_l2_normalize_2/Maximum
=====			
tf_op_layer_l2_normalize_2 (Tensor)	[(None, 32)]	0	sequential_1[1][0] tf_op_layer_l2_normalize_2/Rsqrt[0]
=====			
Total params: 41,376			
Trainable params: 41,376			
Non-trainable params: 0			
=====			

Once you have a movie model, you can create a set of movie feature vectors by using the model to predict using a set of item/movie vectors as input. `item_vecs` is a set of all of the movie vectors. It must be scaled to use with the trained model. The result of the prediction is a 32 entry feature vector for each movie.

```
In [26]: scaled_item_vecs = scalerItem.transform(item_vecs)
vms = model_m.predict(scaled_item_vecs[:,i_s:])
print(f"size of all predicted movie feature vectors: {vms.shape}")
```

size of all predicted movie feature vectors: (847, 32)

Let's now compute a matrix of the squared distance between each movie feature vector and all other movie feature vectors:



We can then find the closest movie by finding the minimum along each row. We will make use of [numpy masked arrays](https://numpy.org/doc/1.21/user/tutorial-ma.html) (<https://numpy.org/doc/1.21/user/tutorial-ma.html>) to avoid selecting the same movie. The masked values along the diagonal won't be included in the computation.

```

In [28]: count = 50 # number of movies to display
dim = len(vms)
dist = np.zeros((dim,dim))

for i in range(dim):
    for j in range(dim):
        dist[i,j] = sq_dist(vms[i, :], vms[j, :])

m_dist = ma.masked_array(dist, mask=np.identity(dist.shape[0])) # mask the diagonal

disp = ["movie1", "genres", "movie2", "genres"]
for i in range(count):
    min_idx = np.argmin(m_dist[i])
    movie1_id = int(item_vecs[i,0])
    movie2_id = int(item_vecs[min_idx,0])
    disp.append( [movie_dict[movie1_id]['title'], movie_dict[movie1_id]['genres'],
                  movie_dict[movie2_id]['title'], movie_dict[movie2_id]['genres']]
    )
table = tabulate.tabulate(disp, tablefmt='html', headers="firstrow")
table

```

Out[28]:

movie1	genres	movie2	
Save the Last Dance (2001)	Drama Romance	Mona Lisa Smile (2003)	
Wedding Planner, The (2001)	Comedy Romance	Mr. Deeds (2002)	
Hannibal (2001)	Horror Thriller	Final Destination 2 (2003)	
Saving Silverman (Evil Woman) (2001)	Comedy Romance	Down with Love (2003)	
Down to Earth (2001)	Comedy Fantasy Romance	Bewitched (2005)	
Mexican, The (2001)	Action Comedy	Rush Hour 2 (2001)	
15 Minutes (2001)	Thriller	Panic Room (2002)	
Enemy at the Gates (2001)	Drama	Kung Fu Hustle (Gong fu) (2004)	
Heartbreakers (2001)	Comedy Crime Romance	Fun with Dick and Jane (2005)	
Spy Kids (2001)	Action Adventure Children Comedy	Tuxedo, The (2002)	
Along Came a Spider (2001)	Action Crime Mystery Thriller	Insomnia (2002)	
Blow (2001)	Crime Drama	25th Hour (2002)	
Bridget Jones's Diary (2001)	Comedy Drama Romance	Punch-Drunk Love (2002)	
Joe Dirt (2001)	Adventure Comedy Mystery Romance	Polar Express, The (2004)	A
Crocodile Dundee in Los Angeles (2001)	Comedy Drama	Bewitched (2005)	
Mummy Returns, The (2001)	Action Adventure Comedy Thriller	Rundown, The (2003)	
Knight's Tale, A (2001)	Action Comedy Romance	Legally Blonde (2001)	
Shrek (2001)	Adventure Animation Children Comedy Fantasy Romance	Tangled (2010)	Adventure Animation
Moulin Rouge (2001)	Drama Romance	Notebook, The (2004)	



movie1	genres	movie2	
Pearl Harbor (2001)	Action Drama Romance	Bridget Jones: The Edge of Reason (2004)	A
Animal, The (2001)	Comedy	Dumb and Dumber: When Harry Met Lloyd (2003)	
Evolution (2001)	Comedy Sci-Fi	Behind Enemy Lines (2001)	
Swordfish (2001)	Action Crime Drama	We Were Soldiers (2002)	
Atlantis: The Lost Empire (2001)	Adventure Animation Children Fantasy	Cloudy with a Chance of Meatballs (2009)	
Lara Croft: Tomb Raider (2001)	Action Adventure	National Treasure: Book of Secrets (2007)	
Dr. Dolittle 2 (2001)	Comedy	Legally Blonde 2: Red, White & Blonde (2003)	
Fast and the Furious, The (2001)	Action Crime Thriller	xXx (2002)	
A.I. Artificial Intelligence (2001)	Adventure Drama Sci-Fi	Bubba Ho- tep (2002)	
Cats & Dogs (2001)	Children Comedy	Robots (2005)	
Scary Movie 2 (2001)	Comedy	Orange County (2002)	
Final Fantasy: The Spirits Within (2001)	Adventure Animation Fantasy Sci-Fi	Madagascar: Escape 2 Africa (2008)	
Legally Blonde (2001)	Comedy Romance	Serendipity (2001)	
Score, The (2001)	Action Drama	Punisher, The (2004)	
Jurassic Park III (2001)	Action Adventure Sci-Fi Thriller	Men in Black II (a.k.a. MIIB) (a.k.a. MIB 2) (2002)	

movie1	genres	movie2
America's Sweethearts (2001)	Comedy Romance	Maid in Manhattan (2002)
Ghost World (2001)	Comedy Drama	Station Agent, The (2003)
Planet of the Apes (2001)	Action Adventure Drama Sci-Fi	Day After Tomorrow, The (2004)
Princess Diaries, The (2001)	Children Comedy Romance	Lake House, The (2006)
Rush Hour 2 (2001)	Action Comedy	Mexican, The (2001)
American Pie 2 (2001)	Comedy	Rat Race (2001)
Others, The (2001)	Drama Horror Mystery Thriller	The Machinist (2004)
Rat Race (2001)	Comedy	American Pie 2 (2001)
Jay and Silent Bob Strike Back (2001)	Adventure Comedy	Mexican, The (2001)
Training Day (2001)	Crime Drama Thriller	Frailty (2001)
Zoolander (2001)	Comedy	Old School (2003)
Serendipity (2001)	Comedy Romance	Legally Blonde (2001)
Mulholland Drive (2001)	Crime Drama Mystery Thriller	Prisoners (2013)
From Hell (2001)	Crime Horror Mystery Thriller	Identity (2003)
Waking Life (2001)	Animation Drama Fantasy	Warm Bodies (2013)
K-PAX (2001)	Drama Fantasy Mystery Sci-Fi	Gosford Park (2001)

The results show the model will generally suggest a movie with similar genre's.



## 6 - Congratulations!

You have completed a content-based recommender system.

This structure is the basis of many commercial recommender systems. The user content can be greatly expanded to incorporate more information about the user if it is available. Items are not limited to movies. This can be used to recommend any item, books, cars or items that are similar to an item in your 'shopping cart'.

**[Please click here if you want to experiment with any of the non-graded code.](#)**