In [1]:
```
# Install TensorFlow
# !pip install -q tensorflow-gpu==2.0.0-rc0

try:
  %tensorflow_version 2.x  # Colab only.
except Exception:
  pass

import tensorflow as tf
print(tf.__version__)
```

```
Colab only includes TensorFlow 2.x; %tensorflow_version has no effect.
2.12.0
```

In [2]:
```
# More imports
from tensorflow.keras.layers import Input, Dense, Embedding, Flatten, \
  Concatenate
from tensorflow.keras.models import Model
from tensorflow.keras.optimizers import SGD, Adam

from sklearn.utils import shuffle

import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
```

In [3]:
```
# data is from: https://grouplens.org/datasets/movielens/
# in case the link changes in the future

!wget -nc http://files.grouplens.org/datasets/movielens/ml-20m.zip
```

```
--2023-05-21 03:46:19--  http://files.grouplens.org/datasets/movielens/ml-20m.zip
Resolving files.grouplens.org (files.grouplens.org)... 128.101.65.152
Connecting to files.grouplens.org (files.grouplens.org)|128.101.65.152|:80... conn
ected.
HTTP request sent, awaiting response... 200 OK
Length: 198702078 (189M) [application/zip]
Saving to: ‘ml-20m.zip’

ml-20m.zip          100%[===================>] 189.50M   102MB/s    in 1.8s

2023-05-21 03:46:21 (102 MB/s) - ‘ml-20m.zip’ saved [198702078/198702078]
```

In [4]:
```
!unzip -n ml-20m.zip
```

```
Archive:  ml-20m.zip
   creating: ml-20m/
  inflating: ml-20m/genome-scores.csv
  inflating: ml-20m/genome-tags.csv
  inflating: ml-20m/links.csv
  inflating: ml-20m/movies.csv
  inflating: ml-20m/ratings.csv
  inflating: ml-20m/README.txt
  inflating: ml-20m/tags.csv
```

In [5]:
```
!ls
```

```
ml-20m  ml-20m.zip  sample_data
```

In [6]:
```
df = pd.read_csv('ml-20m/ratings.csv')
df.head()
```

Out[6]:

	userId	movieId	rating	timestamp
0	1	2	3.5	1112486027
1	1	29	3.5	1112484676
2	1	32	3.5	1112484819
3	1	47	3.5	1112484727
4	1	50	3.5	1112484580

In [7]:
```
# We can't trust the userId and movieId to be numbered 0...N-1
# Let's just set our own ids

# current_user_id = 0
# custom_user_map = {} # old user id > new user id
# def map_user_id(row):
#   global current_user_id, custom_user_map
#   old_user_id = row['userId']
#   if old_user_id not in custom_user_map:
#     custom_user_map[old_user_id] = current_user_id
#     current_user_id += 1
#   return custom_user_map[old_user_id]

# df['new_user_id'] = df.apply(map_user_id, axis=1)

df.userId = pd.Categorical(df.userId)
df['new_user_id'] = df.userId.cat.codes
```

In [8]:
```
# Now do the same thing for movie ids
# current_movie_id = 0
# custom_movie_map = {} # old movie id > new movie id
# def map_movie_id(row):
#   global current_movie_id, custom_movie_map
#   old_movie_id = row['movieId']
#   if old_movie_id not in custom_movie_map:
#     custom_movie_map[old_movie_id] = current_movie_id
#     current_movie_id += 1
#   return custom_movie_map[old_movie_id]

# df['new_movie_id'] = df.apply(map_movie_id, axis=1)

df.movieId = pd.Categorical(df.movieId)
df['new_movie_id'] = df.movieId.cat.codes
```

In [9]:
```
# Get user IDs, movie IDs, and ratings as separate arrays
user_ids = df['new_user_id'].values
```

```
movie_ids = df['new_movie_id'].values
ratings = df['rating'].values
```

In [10]:
```
# Get number of users and number of movies
N = len(set(user_ids))
M = len(set(movie_ids))

# Set embedding dimension
K = 10
```

In [11]:
```
# Make a neural network

# User input
u = Input(shape=(1,))

# Movie input
m = Input(shape=(1,))

# User embedding
u_emb = Embedding(N, K)(u) # output is (num_samples, 1, K)

# Movie embedding
m_emb = Embedding(M, K)(m) # output is (num_samples, 1, K)

# Flatten both embeddings
u_emb = Flatten()(u_emb) # now it's (num_samples, K)
m_emb = Flatten()(m_emb) # now it's (num_samples, K)

# Concatenate user-movie embeddings into a feature vector
x = Concatenate()([u_emb, m_emb]) # now it's (num_samples, 2K)

# Now that we have a feature vector, it's just a regular ANN
x = Dense(1024, activation='relu')(x)
# x = Dense(400, activation='relu')(x)
# x = Dense(400, activation='relu')(x)
x = Dense(1)(x)
```

In [12]:
```
# Build the model and compile
model = Model(inputs=[u, m], outputs=x)
model.compile(
  loss='mse',
  optimizer=SGD(learning_rate=0.08, momentum=0.9),
)
```

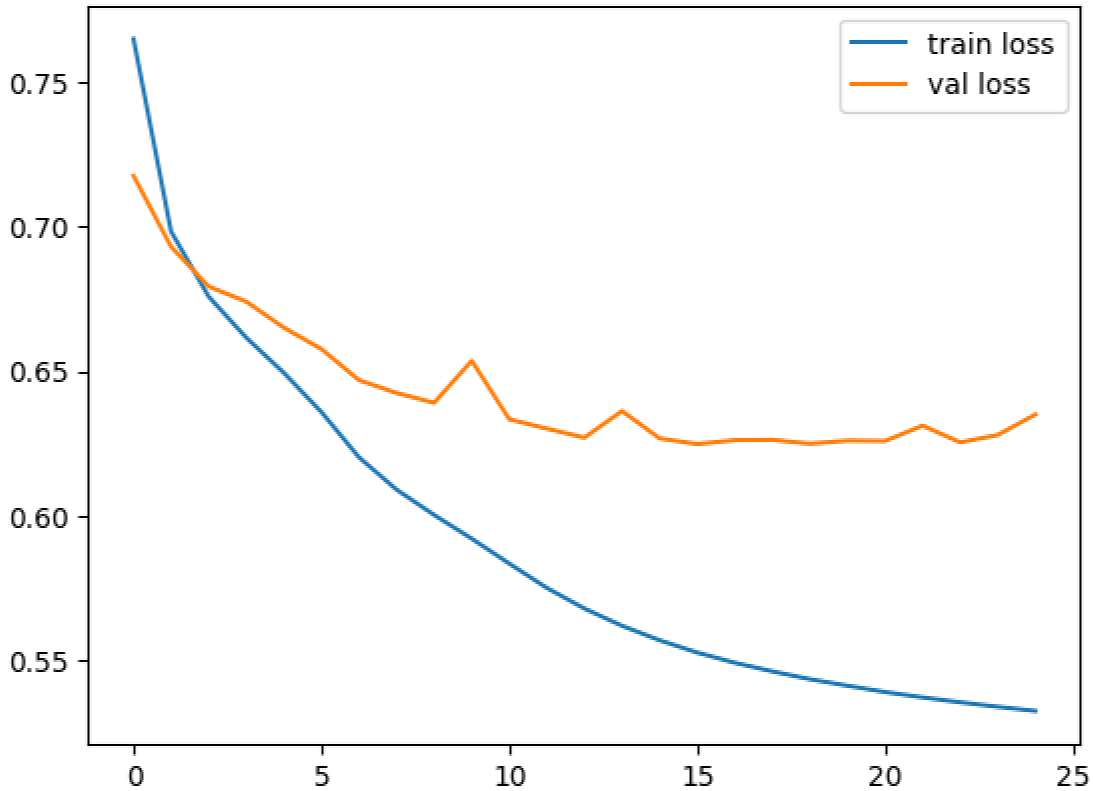
In [13]:
```
# split the data
user_ids, movie_ids, ratings = shuffle(user_ids, movie_ids, ratings)
Ntrain = int(0.8 * len(ratings))
train_user = user_ids[:Ntrain]
train_movie = movie_ids[:Ntrain]
train_ratings = ratings[:Ntrain]

test_user = user_ids[Ntrain:]
test_movie = movie_ids[Ntrain:]
test_ratings = ratings[Ntrain:]
```

```
# center the ratings
avg_rating = train_ratings.mean()
train_ratings = train_ratings - avg_rating
test_ratings = test_ratings - avg_rating
```

In [14]:
```
r = model.fit(
  x=[train_user, train_movie],
  y=train_ratings,
  epochs=25,
  batch_size=1024,
  verbose=2, # goes a little faster when you don't print the progress bar
  validation_data=([test_user, test_movie], test_ratings),
)
```

```
Epoch 1/25
15626/15626 - 81s - loss: 0.7649 - val_loss: 0.7175 - 81s/epoch - 5ms/step
Epoch 2/25
15626/15626 - 60s - loss: 0.6983 - val_loss: 0.6930 - 60s/epoch - 4ms/step
Epoch 3/25
15626/15626 - 60s - loss: 0.6758 - val_loss: 0.6793 - 60s/epoch - 4ms/step
Epoch 4/25
15626/15626 - 63s - loss: 0.6616 - val_loss: 0.6740 - 63s/epoch - 4ms/step
Epoch 5/25
15626/15626 - 60s - loss: 0.6494 - val_loss: 0.6650 - 60s/epoch - 4ms/step
Epoch 6/25
15626/15626 - 64s - loss: 0.6358 - val_loss: 0.6576 - 64s/epoch - 4ms/step
Epoch 7/25
15626/15626 - 59s - loss: 0.6202 - val_loss: 0.6469 - 59s/epoch - 4ms/step
Epoch 8/25
15626/15626 - 59s - loss: 0.6090 - val_loss: 0.6424 - 59s/epoch - 4ms/step
Epoch 9/25
15626/15626 - 63s - loss: 0.6002 - val_loss: 0.6390 - 63s/epoch - 4ms/step
Epoch 10/25
15626/15626 - 60s - loss: 0.5920 - val_loss: 0.6536 - 60s/epoch - 4ms/step
Epoch 11/25
15626/15626 - 63s - loss: 0.5834 - val_loss: 0.6333 - 63s/epoch - 4ms/step
Epoch 12/25
15626/15626 - 62s - loss: 0.5750 - val_loss: 0.6301 - 62s/epoch - 4ms/step
Epoch 13/25
15626/15626 - 63s - loss: 0.5679 - val_loss: 0.6270 - 63s/epoch - 4ms/step
Epoch 14/25
15626/15626 - 60s - loss: 0.5619 - val_loss: 0.6362 - 60s/epoch - 4ms/step
Epoch 15/25
15626/15626 - 60s - loss: 0.5569 - val_loss: 0.6267 - 60s/epoch - 4ms/step
Epoch 16/25
15626/15626 - 63s - loss: 0.5526 - val_loss: 0.6247 - 63s/epoch - 4ms/step
Epoch 17/25
15626/15626 - 63s - loss: 0.5491 - val_loss: 0.6261 - 63s/epoch - 4ms/step
Epoch 18/25
15626/15626 - 60s - loss: 0.5461 - val_loss: 0.6262 - 60s/epoch - 4ms/step
Epoch 19/25
15626/15626 - 60s - loss: 0.5434 - val_loss: 0.6249 - 60s/epoch - 4ms/step
Epoch 20/25
15626/15626 - 60s - loss: 0.5412 - val_loss: 0.6259 - 60s/epoch - 4ms/step
Epoch 21/25
15626/15626 - 60s - loss: 0.5390 - val_loss: 0.6258 - 60s/epoch - 4ms/step
Epoch 22/25
15626/15626 - 59s - loss: 0.5371 - val_loss: 0.6311 - 59s/epoch - 4ms/step
Epoch 23/25
15626/15626 - 59s - loss: 0.5354 - val_loss: 0.6253 - 59s/epoch - 4ms/step
Epoch 24/25
15626/15626 - 59s - loss: 0.5339 - val_loss: 0.6279 - 59s/epoch - 4ms/step
Epoch 25/25
15626/15626 - 59s - loss: 0.5324 - val_loss: 0.6350 - 59s/epoch - 4ms/step
```

In [15]:
```
# plot losses
plt.plot(r.history['loss'], label="train loss")
plt.plot(r.history['val_loss'], label="val loss")
plt.legend()
plt.show()
```



In [16]:
```
# is this on par with other approaches?
# https://datascience.stackexchange.com/questions/29740/benchmark-result-for-moviel
np.sqrt(0.6259)
```

Out[16]: 0.7911384202527394