

# Matrix Factorization and Movie Recommendations

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Code



<https://github.com/yanneta/pytorch-tutorials/blob/master/collaborative-filtering-nn.ipynb>



**Yannet**  
yanneta

I am an Assistant Professor of Data Science at University of San Francisco. I teach Machine Learning and Deep Learning.

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235 contributions in the last year

Contribution activity

Jump to 2018

August 2018

Created 11 commits in 2 repositories

yanneta/pytorch-tutorials 10 commits

yanneta/dl-course 1 commit

## Collaborative Filtering with Neural Networks

In this notebook we will write a matrix factorization model in pytorch to solve a recommendation problem. Then we will write a more general neural model for the same problem.

The MovieLens dataset (ml-latest-small) describes 5-star rating and free-text tagging activity from MovieLens, a movie recommendation service. It contains 100004 ratings and 1296 tag applications across 9125 movies. <https://grouplens.org/datasets/movielens/>. To get the data:

```
wget http://files.grouplens.org/datasets/movielens/ml-latest-small.zip
```

## MovieLens dataset

```
[1]: from pathlib import Path
import pandas as pd
import numpy as np

[2]: PATH = Path("/Users/yinterian/teaching/deeplearning/data/ml-latest-small/")
list(PATH.iterdir())

[2]: [PosixPath('/Users/yinterian/teaching/deeplearning/data/ml-latest-small/links.csv'),
PosixPath('/Users/yinterian/teaching/deeplearning/data/ml-latest-small/movies.csv'),
PosixPath('/Users/yinterian/teaching/deeplearning/data/ml-latest-small/ratings.csv'),
PosixPath('/Users/yinterian/teaching/deeplearning/data/ml-latest-small/README.txt'),
PosixPath('/Users/yinterian/teaching/deeplearning/data/ml-latest-small/tags.csv'),
PosixPath('/Users/yinterian/teaching/deeplearning/data/ml-latest-small/tiny_training2.csv'),
PosixPath('/Users/yinterian/teaching/deeplearning/data/ml-latest-small/tiny_val2.csv')]

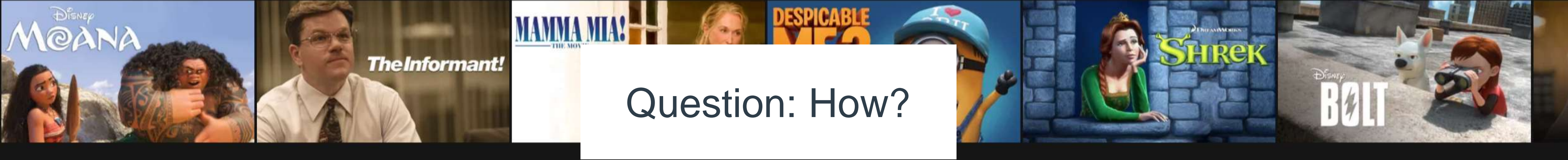
[3]: ! head $PATH/ratings.csv
```



Binge-worthy TV Shows



Comedies



TV Action & Adventure



New Releases





# Netflix Universe



Ana



Betty



Carlos



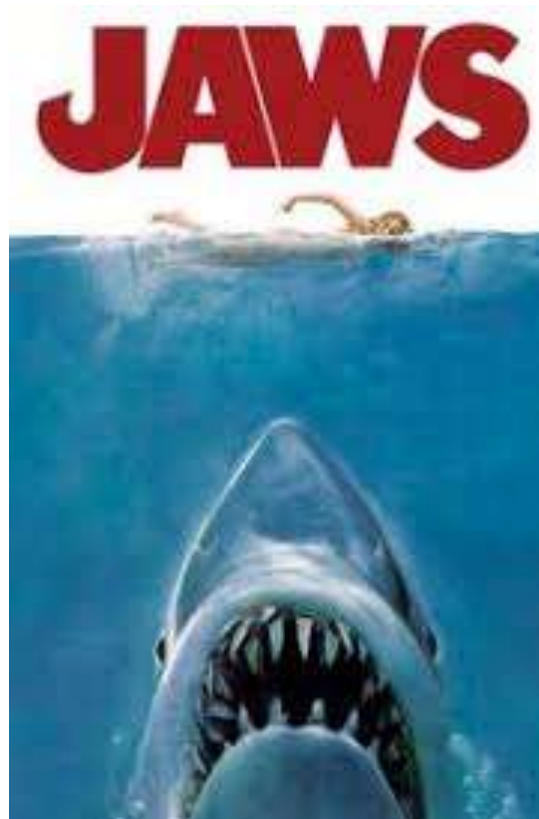
Dana



Movie 1



Movie 2



Movie 3



Movie 4



Movie 5

# Netflix ratings



Ana










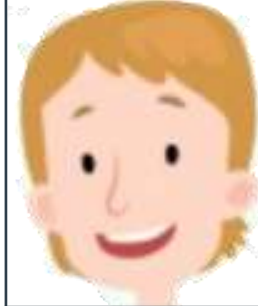
Movie 5





	M1	M2	M3	M4	M5
	1	3	2	5	4
	2	1	1	1	5
	3	2	3	1	5
	2	4	1	5	2



# How do humans behave?





	M 1	M 2	M 3	M 4	M 5
	3	3	3	3	3
	3	3	3	3	3
	3	3	3	3	3
	3	3	3	3	3

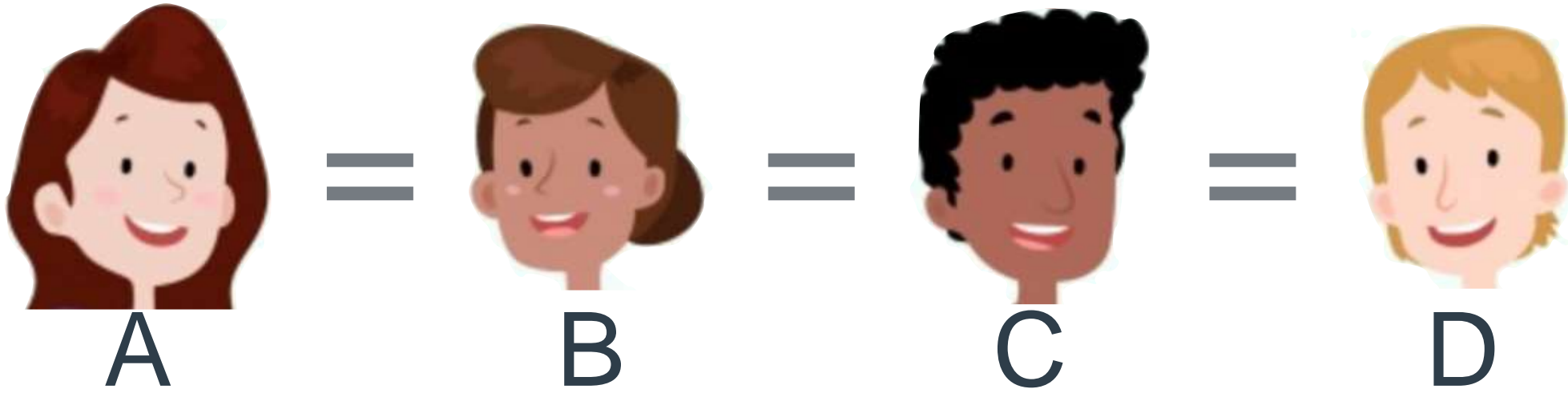
	M 1	M 2	M 3	M 4	M 5
	3	1	1	3	1
	1	2	4	1	3
	3	1	1	3	1
	4	3	5	4	4

	M 1	M 2	M 3	M 4	M 5
	1	3	2	5	4
	2	1	1	1	5
	3	2	3	1	5
	2	4	1	5	2







# Dependent Rows and Columns




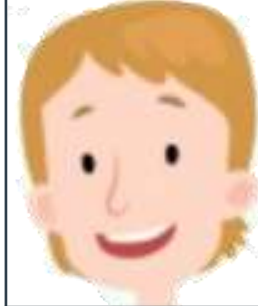
	M1	M2	M3	M4	M5
	3	3	3	3	3
	3	3	3	3	3
	3	3	3	3	3
	3	3	3	3	3







$$M1 = M2 = M3 = M4 = M5$$

# How do humans behave?

	M 1	M 2	M 3	M 4	M 5
	3	3	3	3	3
	3	3	3	3	3
	3	3	3	3	3
	3	3	3	3	3





	M 1	M 2	M 3	M 4	M 5
	3	1	1	3	1
	1	2	4	1	3
	3	1	1	3	1
	4	3	5	4	4

	M 1	M 2	M 3	M 4	M 5
	1	3	2	5	4
	2	1	1	1	5
	3	2	3	1	5
	2	4	1	5	2





# Independent Rows and Columns

	M1	M2	M3	M4	M5
	1	3	2	5	4
	2	1	1	1	5
	3	2	3	1	5
	2	4	1	5	2



M1





M2




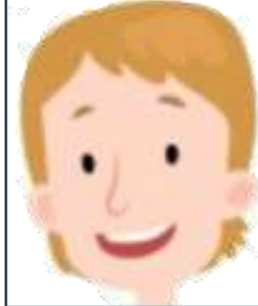
M3





M4

M5

# How do humans behave?

	M 1	M 2	M 3	M 4	M 5
	3	3	3	3	3
	3	3	3	3	3
	3	3	3	3	3
	3	3	3	3	3





	M 1	M 2	M 3	M 4	M 5
	3	1	1	3	1
	1	2	4	1	3
	3	1	1	3	1
	4	3	5	4	4

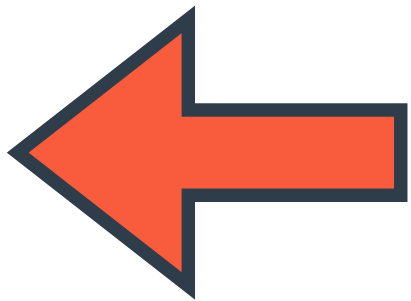
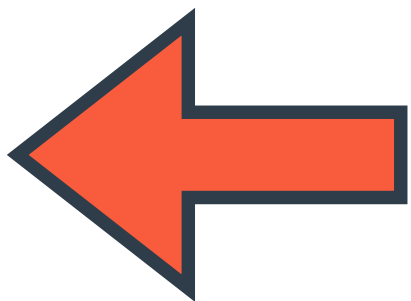
	M 1	M 2	M 3	M 4	M 5
	1	3	2	5	4
	2	1	1	1	5
	3	2	3	1	5
	2	4	1	5	2











# Dependent Rows and Columns

	M1	M2	M3	M4	M5
	3	1	1	3	1
					
	3	1	1	3	1
					



 =   
A C

# Dependent Rows and Columns

	M1	M2	M3	M4	M5
	3			3	
	1			1	
	3			3	
	4			4	



**M1 = M4**







Mall Cop

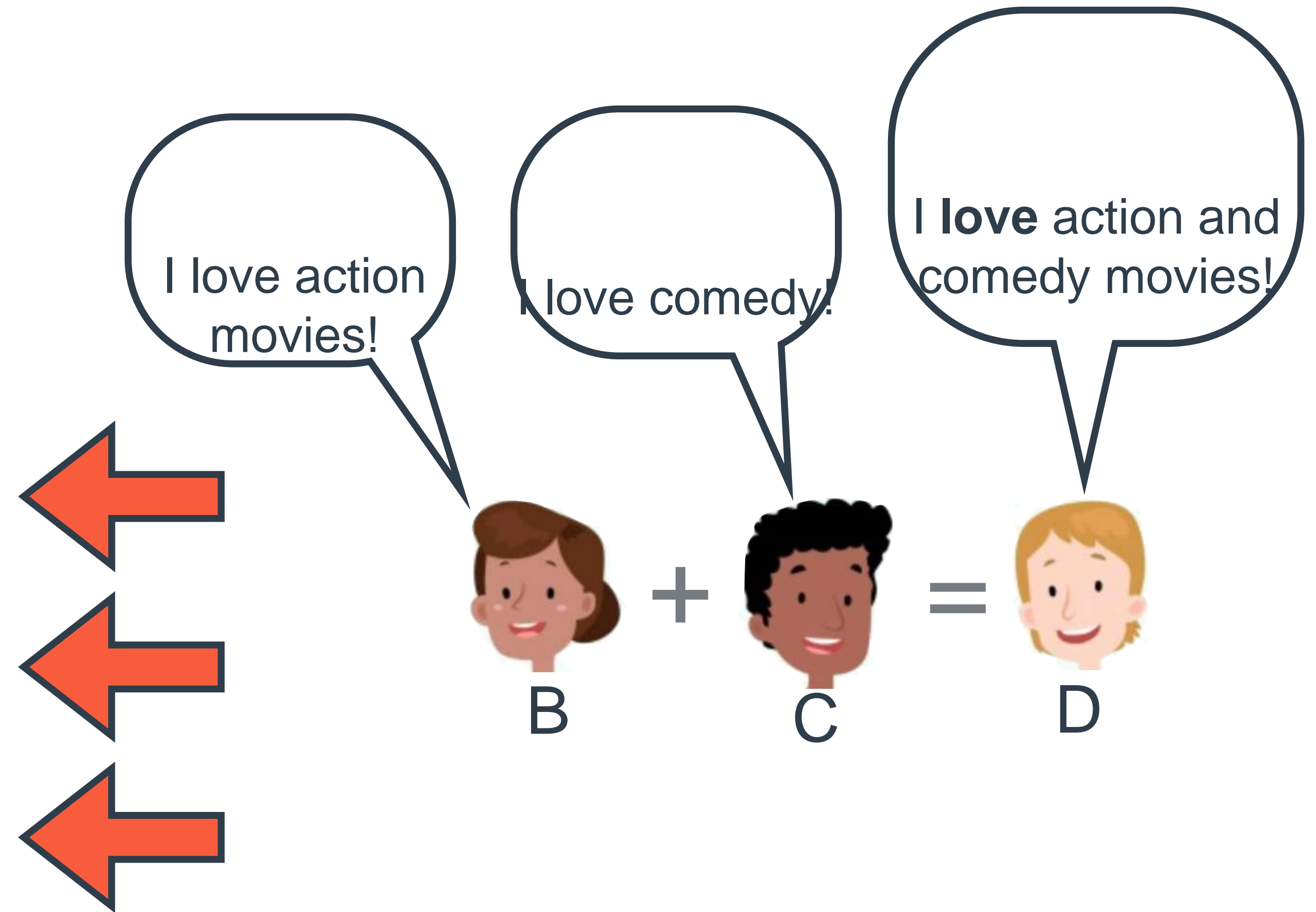


Observe  
and  
Report







# Dependent Rows and Columns

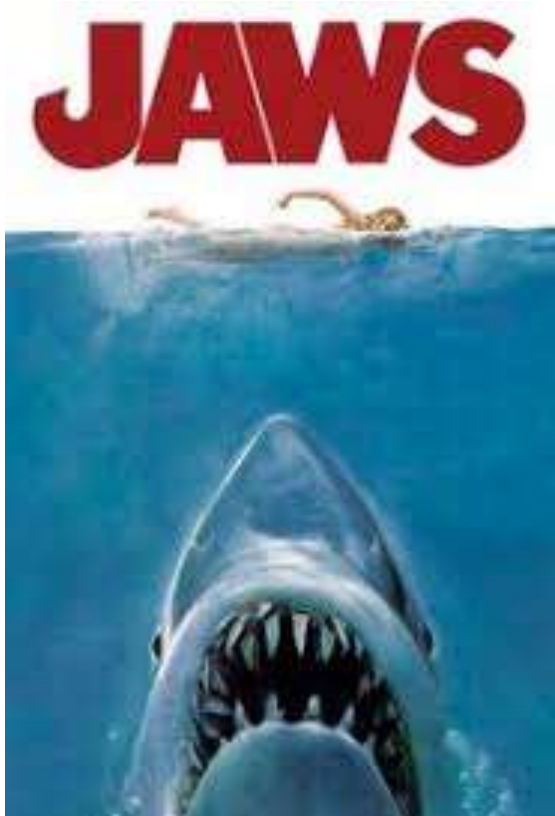
	M1	M2	M3	M4	M5
					
	1	2	4	1	3
	3	1	1	3	1
	4	3	5	4	4



# Dependent Rows and Columns

	M1	M2	M3	M4	M5
		1	1		1
		2	4		3
		1	1		1
		3	5		4





**M5** = Average(**M2**, **M3**)

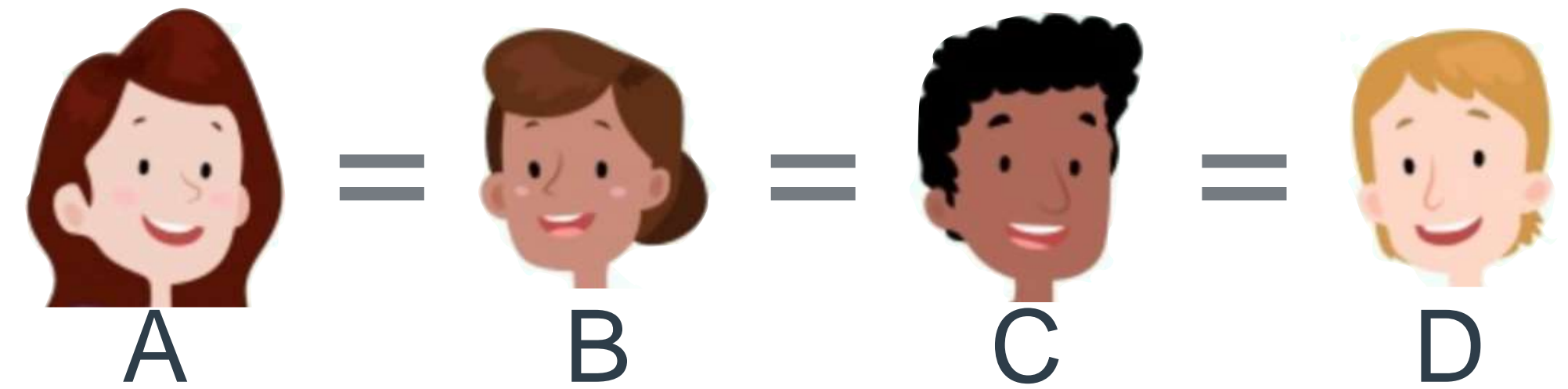




Guessing ratings

# Recommender Systems

	M1	M2	M3	M4	M5
	3	3	3	3	3
	3	3	3	3	3
	3	3	3	?	3
	3	3	3	3	3







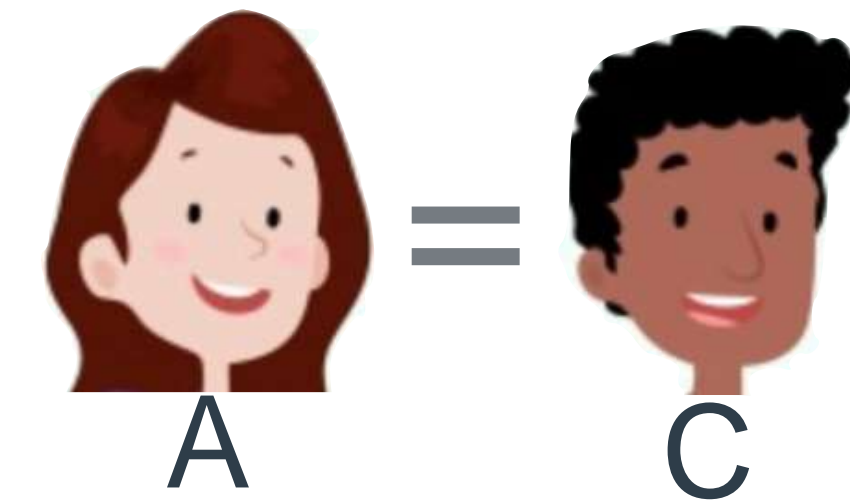
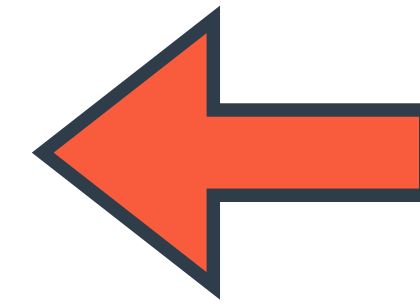
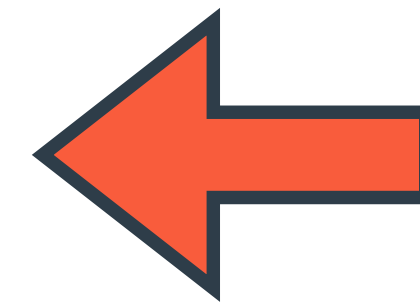
**M1 = M2 = M3 = M4 = M5**





# Recommender Systems

	M1	M2	M3	M4	M5
	3	1	1	3	1
	1	2	4	1	3
	3	1	1	3	
	4	3	5	4	4



Movie 5

Question: How do we figure out all these dependencies?



Answer: Matrix Factorization





# Factorization

$$6 \times 4 = 24$$



# Matrix Factorization

this  $\times$  that =

	M1	M2	M3	M4	M5
	3	1	1	3	1
	1	2	4	1	3
	3	1	1	3	1
	4	3	5	4	4

# Features



Has a Sad Dog



Comedy



Drama



Action



Meryl Streep



Sexy Canadian Ryan



Big Boat



Scary



# Features



Comedy



Action

# Dot Product



Comedy



Action



Ana



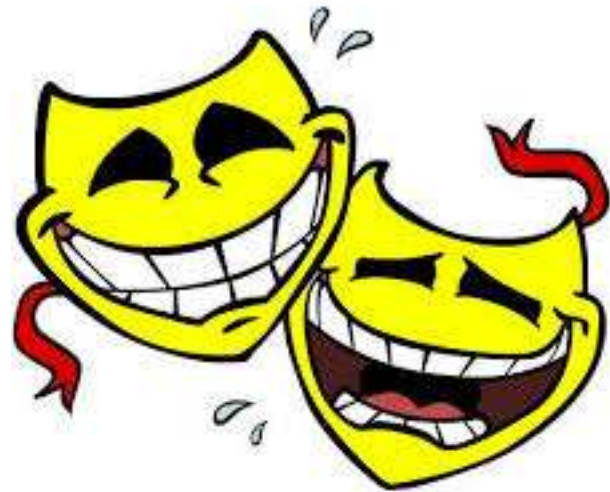
3

1





# Dot Product



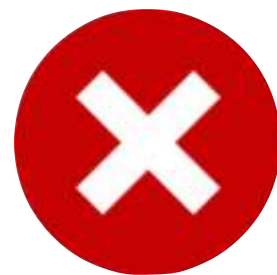
Comedy



Action



Betty



3

1



# Dot Product



Comedy



Action



Dana



1















3





# Categories

	 Comedy	 Action
M1	3	1
M2	1	2
M3	1	4
M4	3	1
M5	1	3

	 Comedy	 Action
		
		
		
		



Movie 1

Ana















$3 + 1 = 3$






# Categories


	 Comedy	 Action
M1	3	1
M2	1	2
M3	1	4
M4	3	1
M5	1	3

	 Comedy	 Action
		
		
		
		

  
Betty

Movie 1

3





+

1

=

1




















# Categories

	 Comedy	 Action
M1	3	1
M2	1	2
M3	1	4
M4	3	1
M5	1	3

	 Comedy	 Action
		
		
		
		



Dana

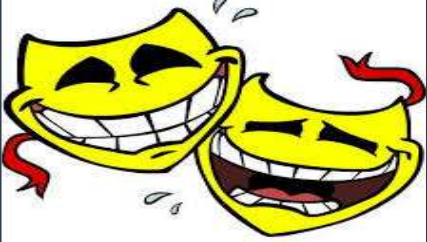

Movie 5





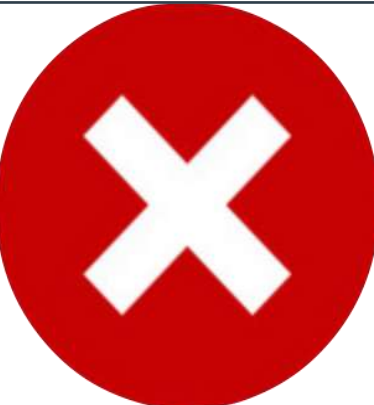

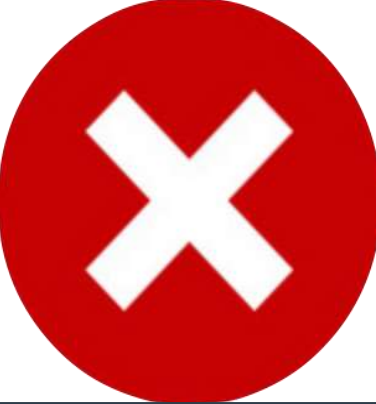



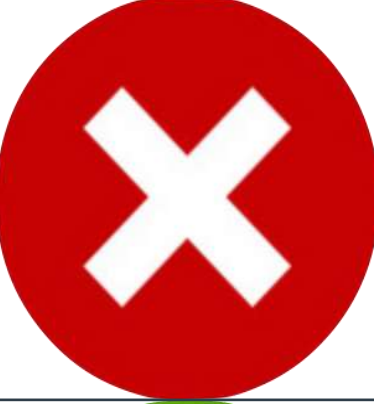



 1 +  3 = 4









# Matrix Factorization

	 Comedy	 Action
M1	3	1
M2	1	2
M3	1	4
M4	3	1
M5	1	3

	 Comedy	 Action
		
		
		
		

=

	M1	M2	M3	M4	M5
	3	1	1	3	1
	1	2	4	1	3
	3	1	1	3	1
	4	3	5	4	4





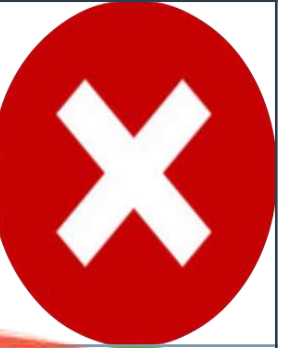





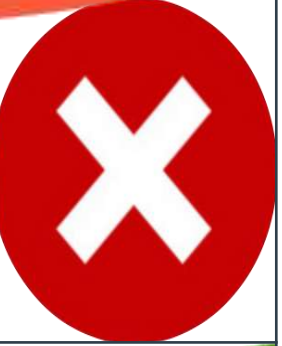








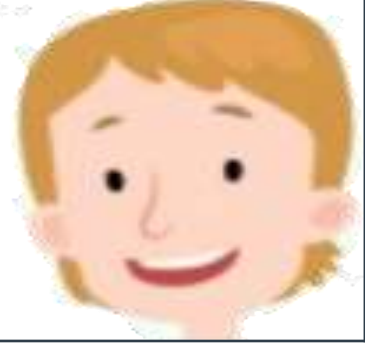
# Factorization

$$6 \times 4 = 24$$

# Matrix Factorization

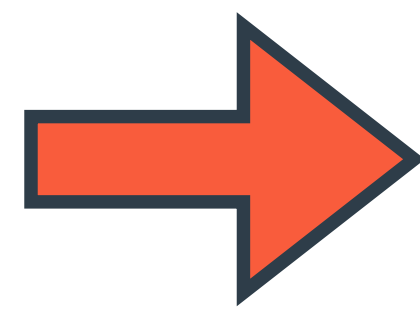
	M1	M2	M3	M4	M5
 Comedy	3	1	1	3	1
 Action	1	2	4	1	3















	 Comedy	 Action
 A		
 B		
 C		
 D		

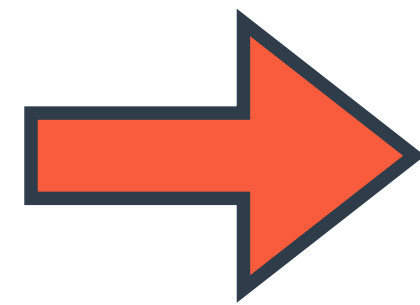
	M1	M2	M3	M4	M5
	3	1	1	3	1
	1	2	4	1	3
	3	1	1	3	1
	4	3	5	4	4





# Matrix Factorization

	M1	M2	M3	M4	M5
 Comedy	3	1	1	3	1
 Action	1	2	4	1	3





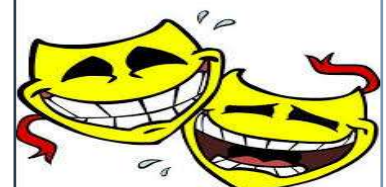

	 Comedy	 Action
 A		
 B		
 C		
 D		





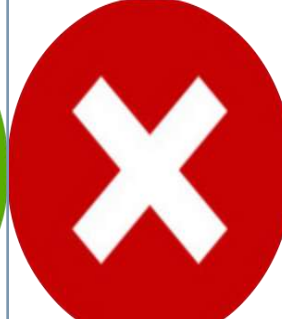

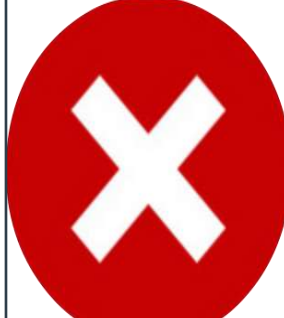



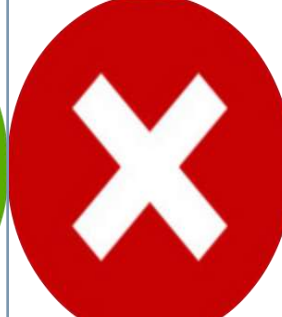









	M1	M2	M3	M4	M5
	3	1	1	3	1
	1	2	4	1	3
	3	1	1	3	1
	4	3	5	4	4





# Matrix Factorization

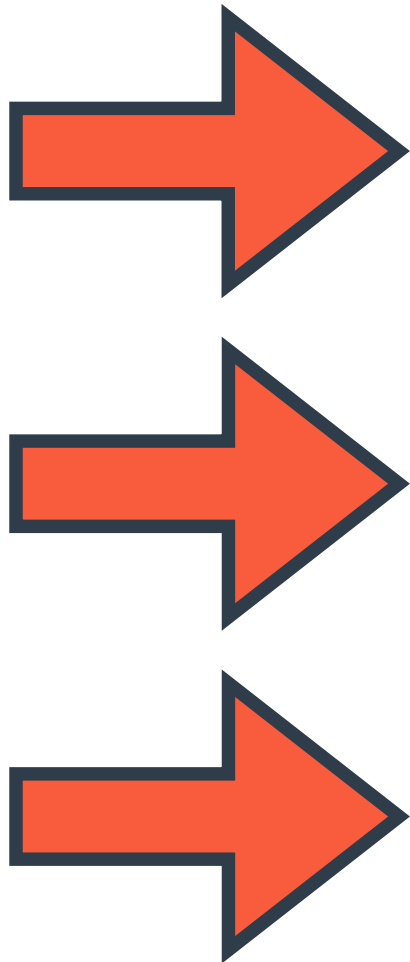
		M2	M3		M5
 Comedy	3	1	1	3	1
 Action	1	2	4	1	3















	 Comedy	 Action
 A		
 B		
 C		
 D		





	M1	M2	M3	M4	M5
	3	1	1	3	1
	1	2	4	1	3
	3	1	1	3	1
	4	3	5	4	4

# Matrix Factorization

	M1	M2	M3	M4	M5
 Comedy	3	1	1	3	1
 Action	1	2	4	1	3




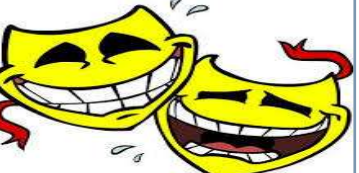







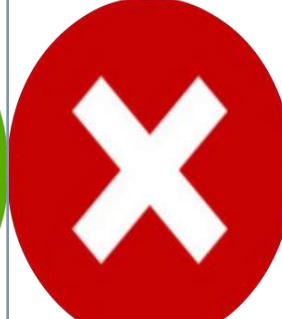

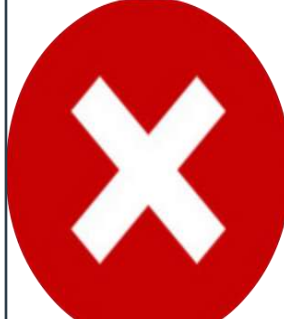



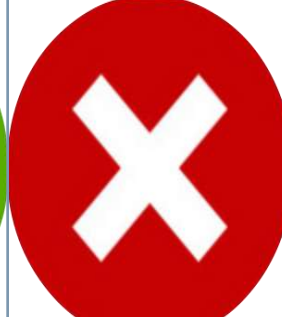



	 Comedy	 Action
 A		
 B		
 C		
 D		





	M1	M2	M3	M4	M5
	3	1	1	3	1
	1	2	4	1	3
	3	1	1	3	1
	4	3	5	4	4



# Matrix Factorization

	M1			M4	
 Comedy	3	1	1	3	1
 Action	1	2	4	1	3

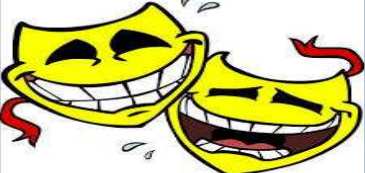

	 Comedy	 Action
 A		
 B		
 C		
 D		















	M1	M2	M3	M4	M5
	3	1	1	3	1
	1	2	4	1	3
	3	1	1	3	1
	4	3	5	4	4







Storage

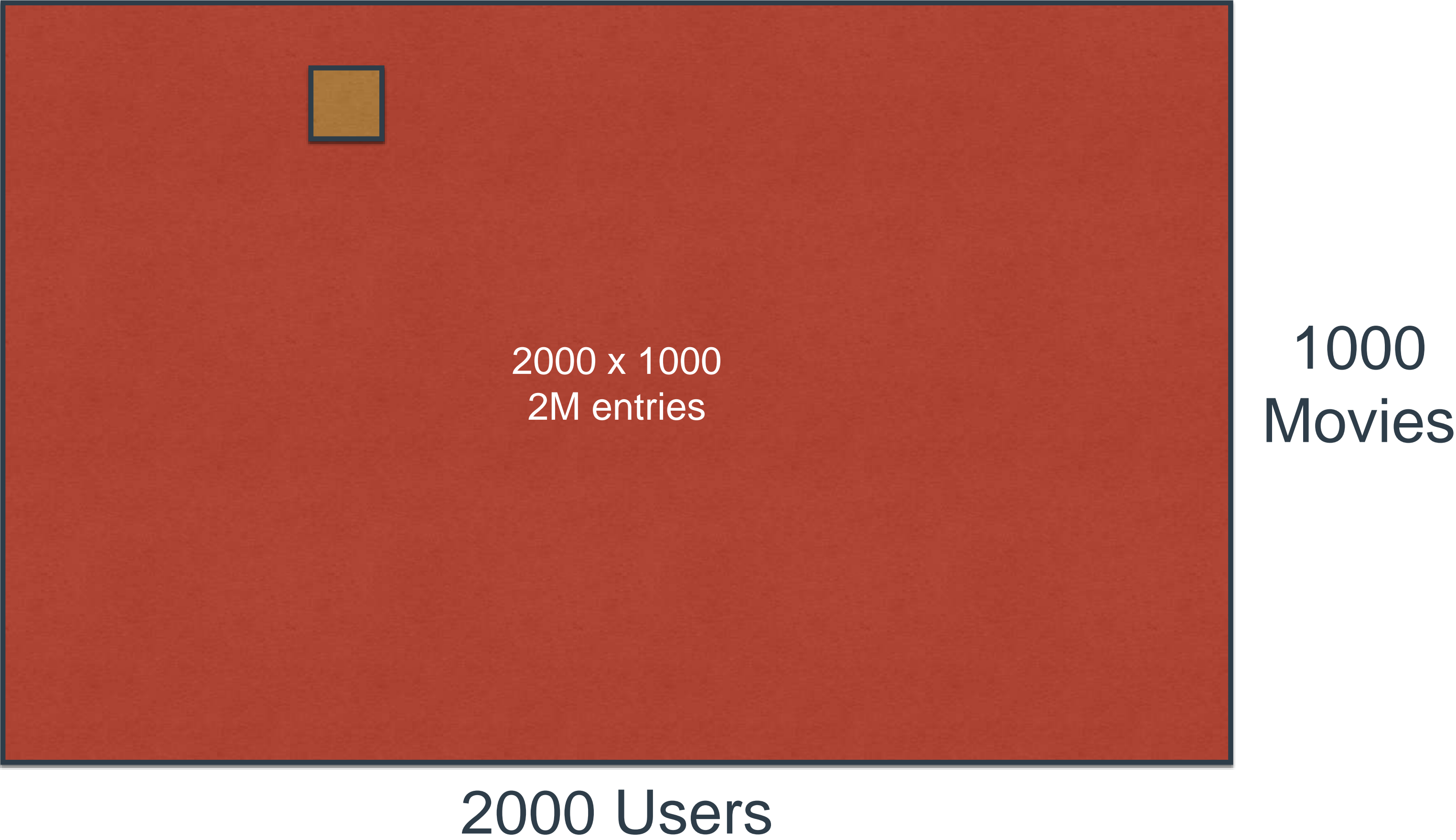
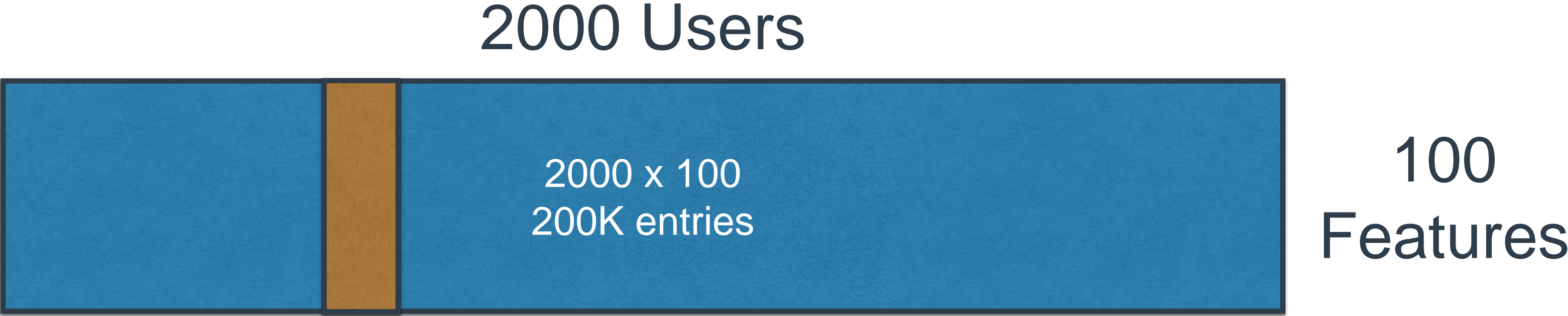
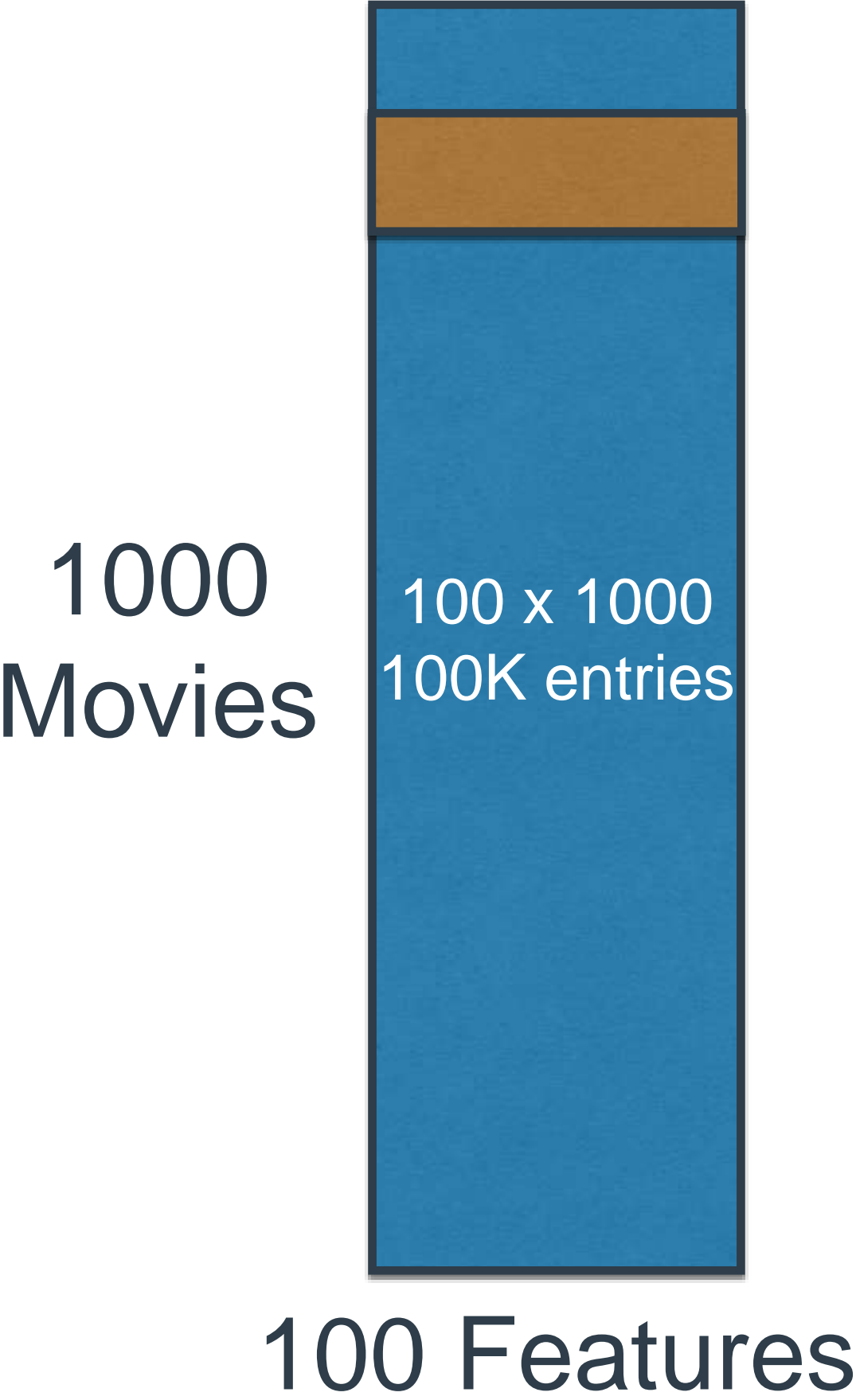
# Matrix Factorization

	M1	M2	M3	M4	M5
 Comedy	3	1	1	3	1
 Action	1	2	4	1	3

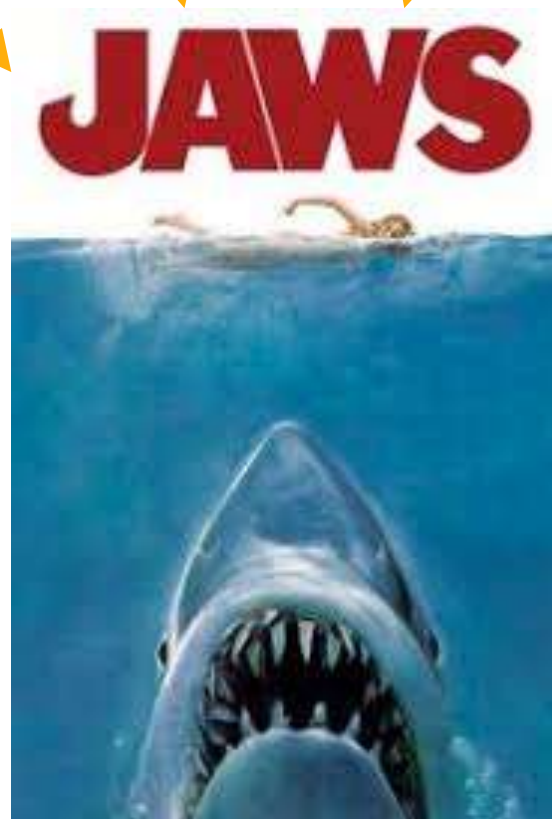
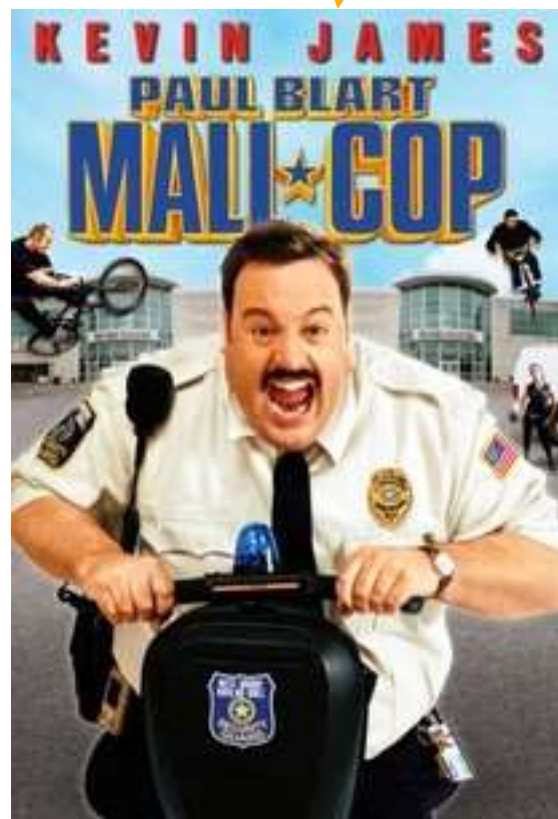
	 Comedy	 Action
 A		
 B		
 C		
 D		

	M1	M2	M3	M4	M5
	3	1	1	3	1
	1	2	4	1	3
	3	1	1	3	1
	4	3	5	4	4

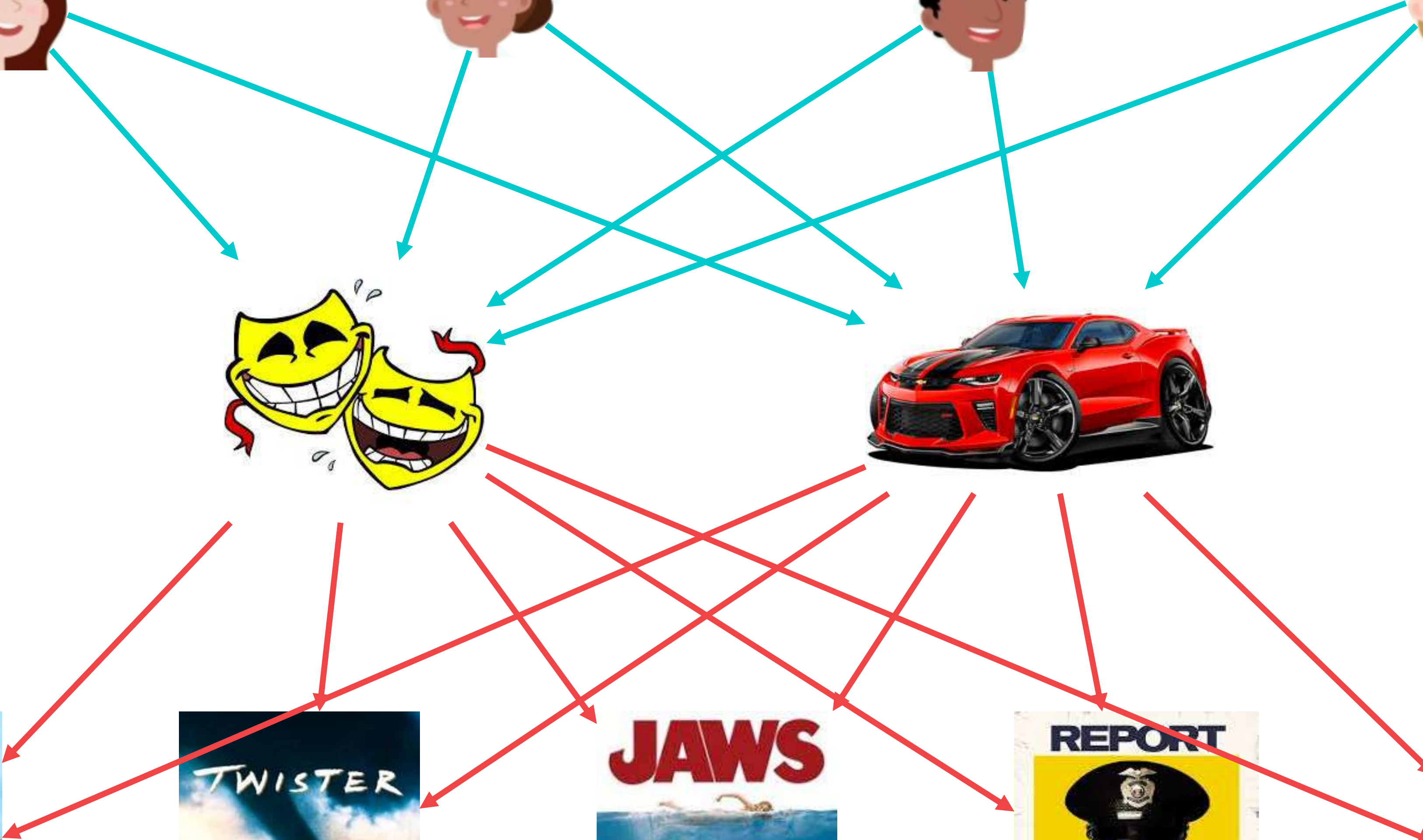
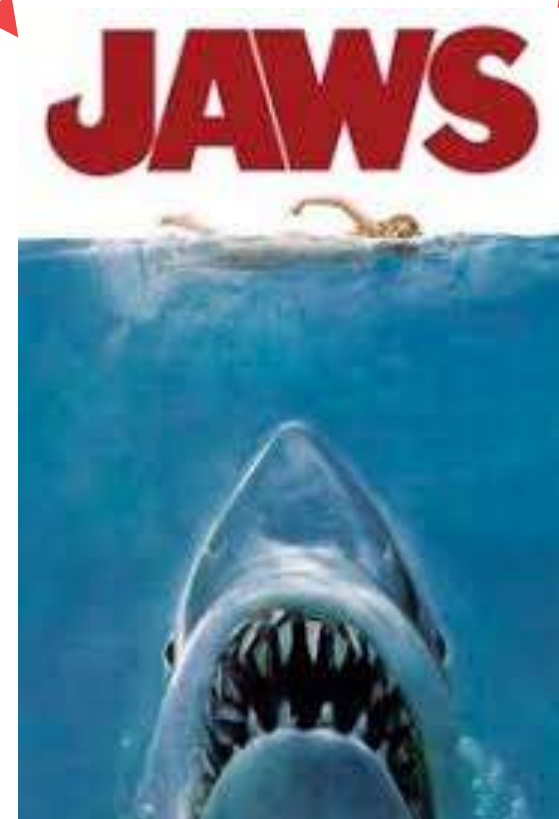
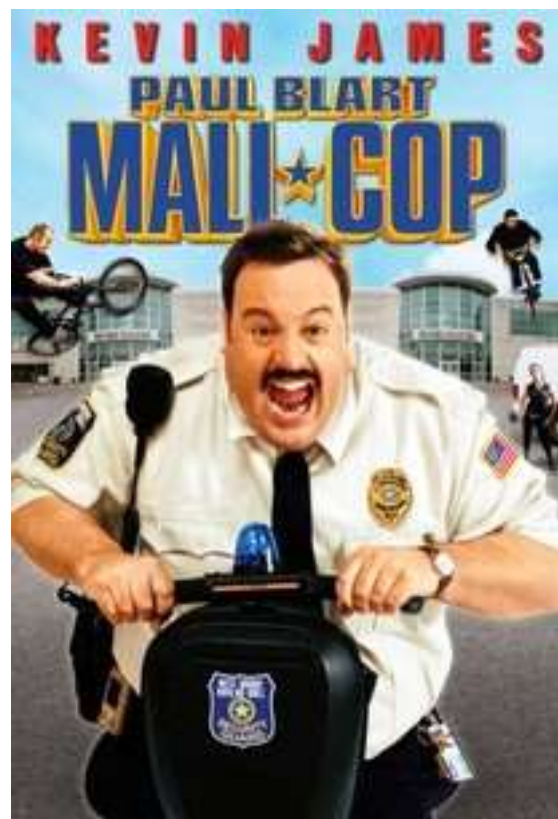
# Matrix Factorization





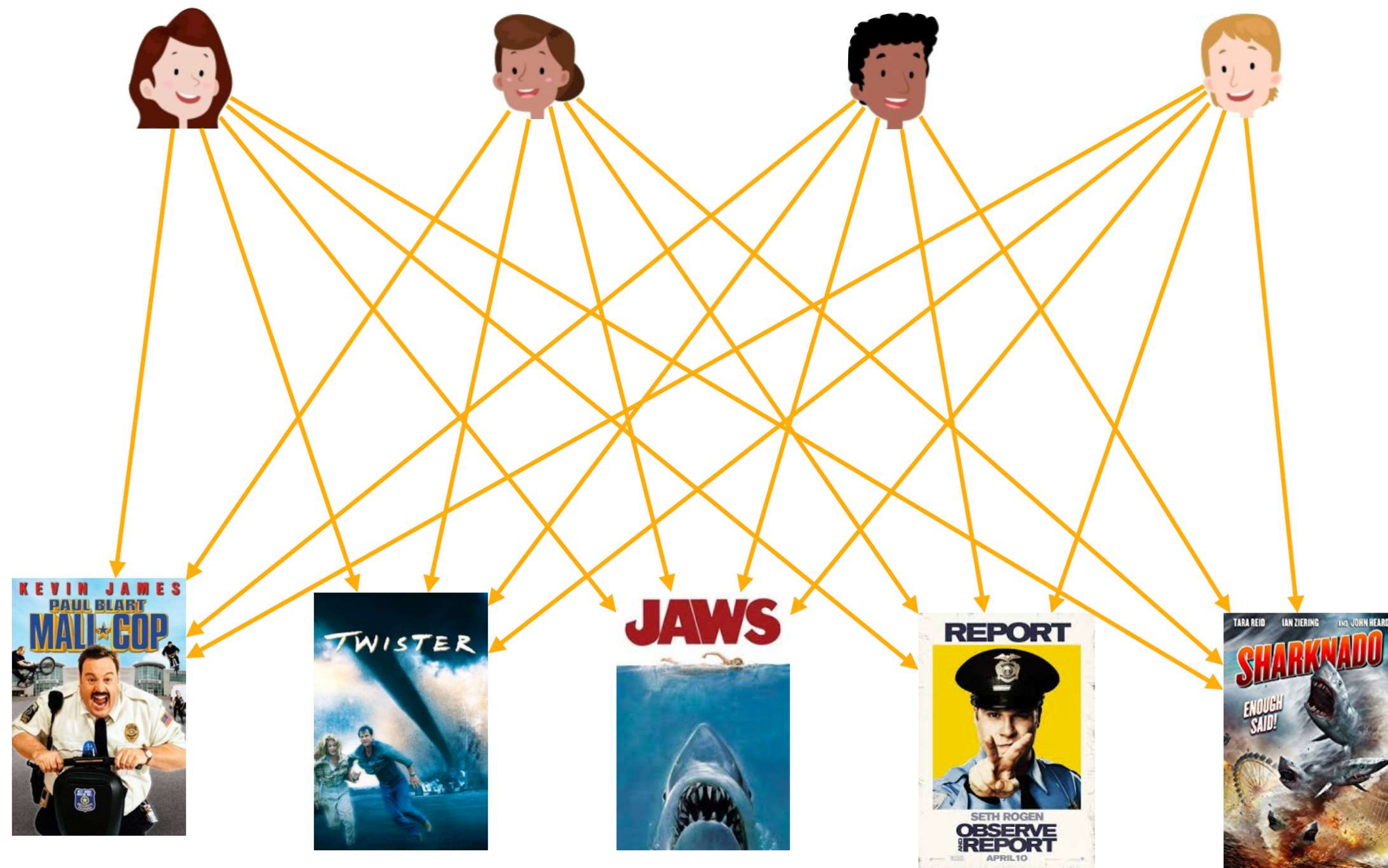




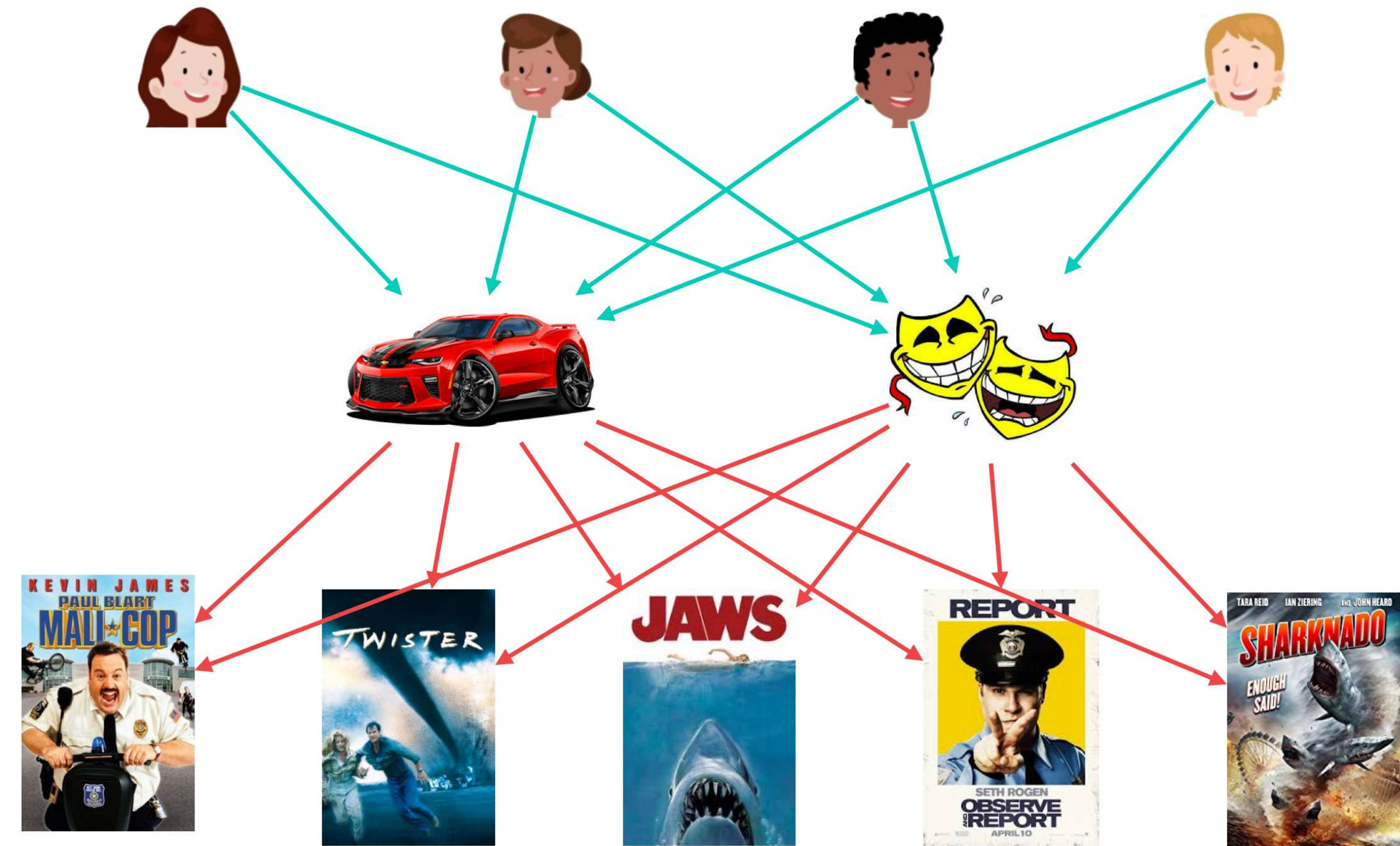




# Quiz: How many parameters (arrows)?



20 parameters



18 parameters

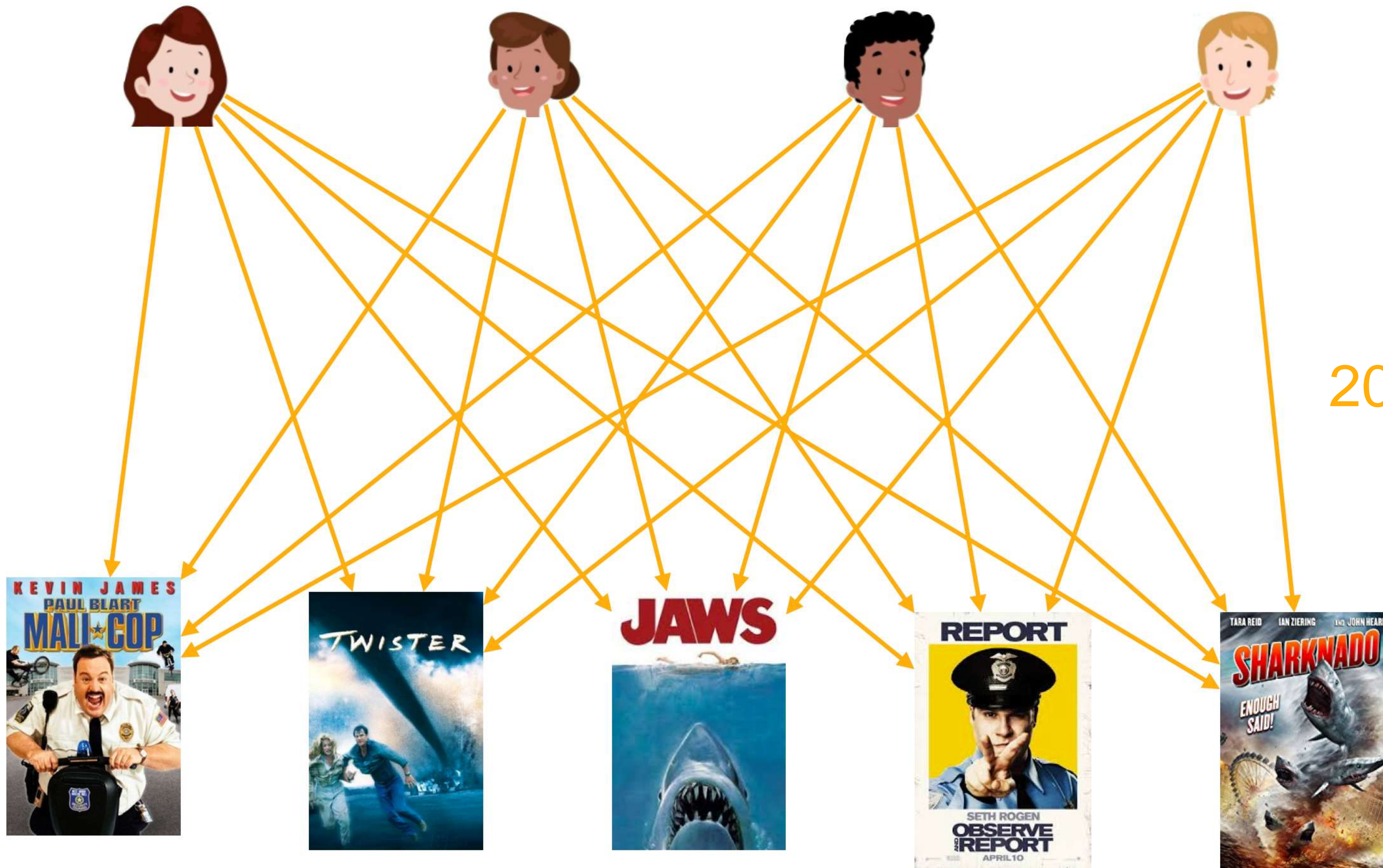


# Quiz: How many parameters?

2000 users

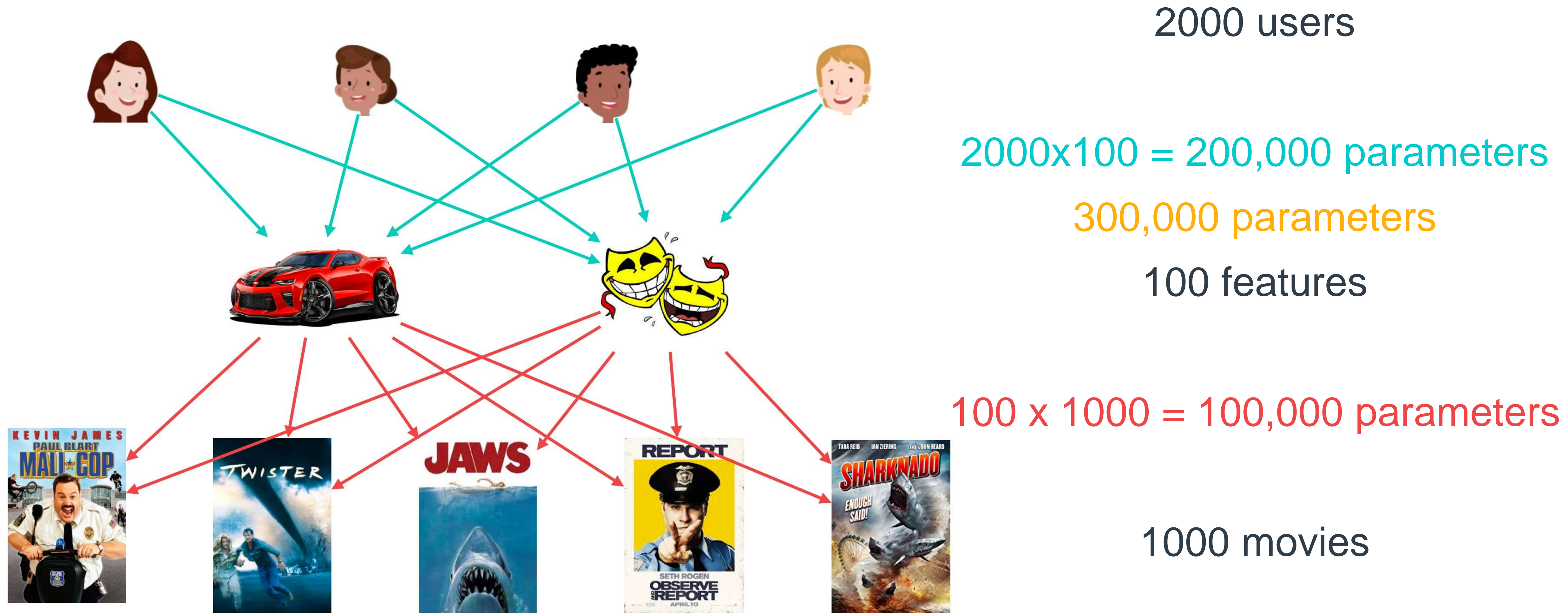
$2000 \times 1000 = 2,000,000$  parameters

1000 movies



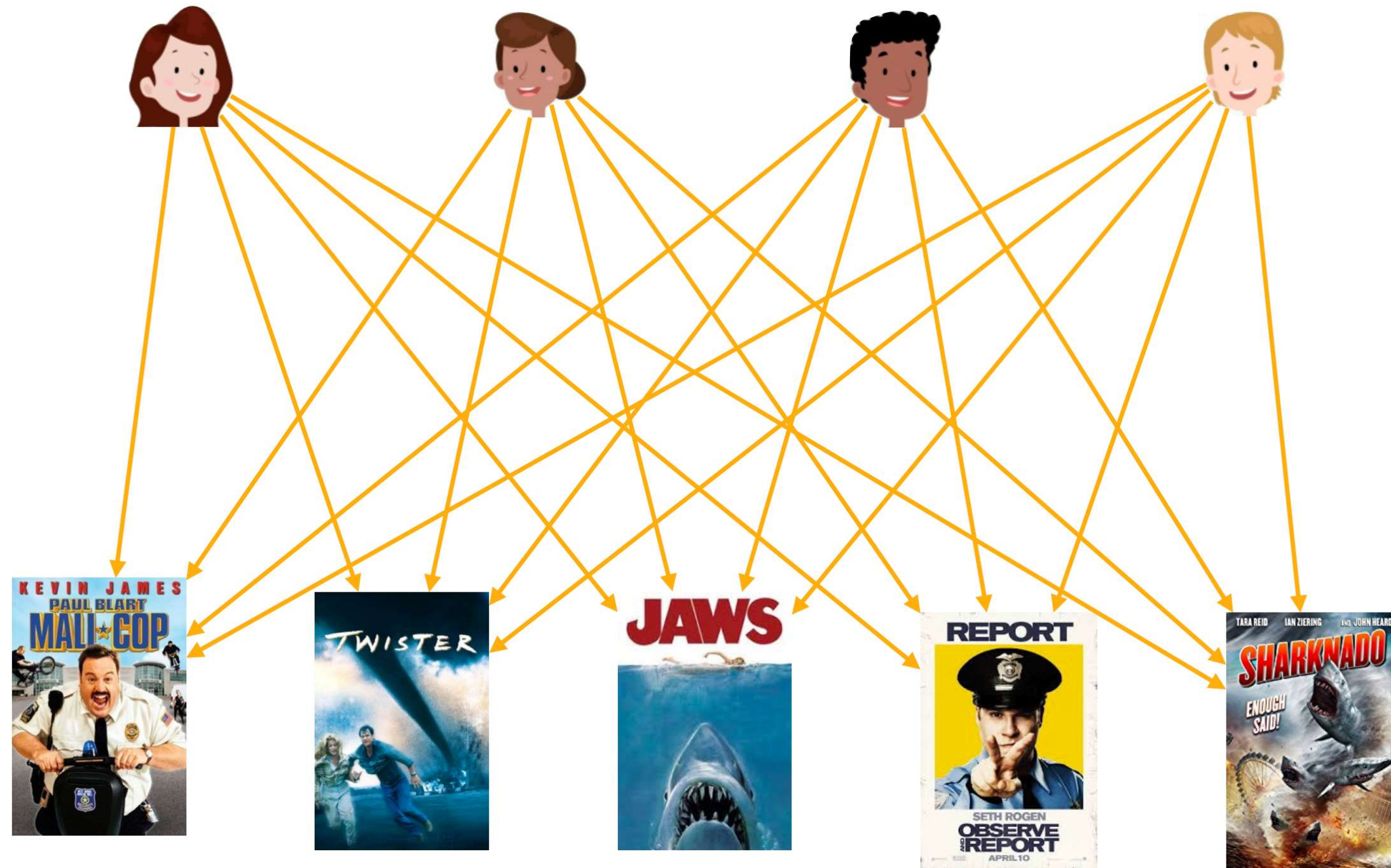


# Quiz: How many parameters?

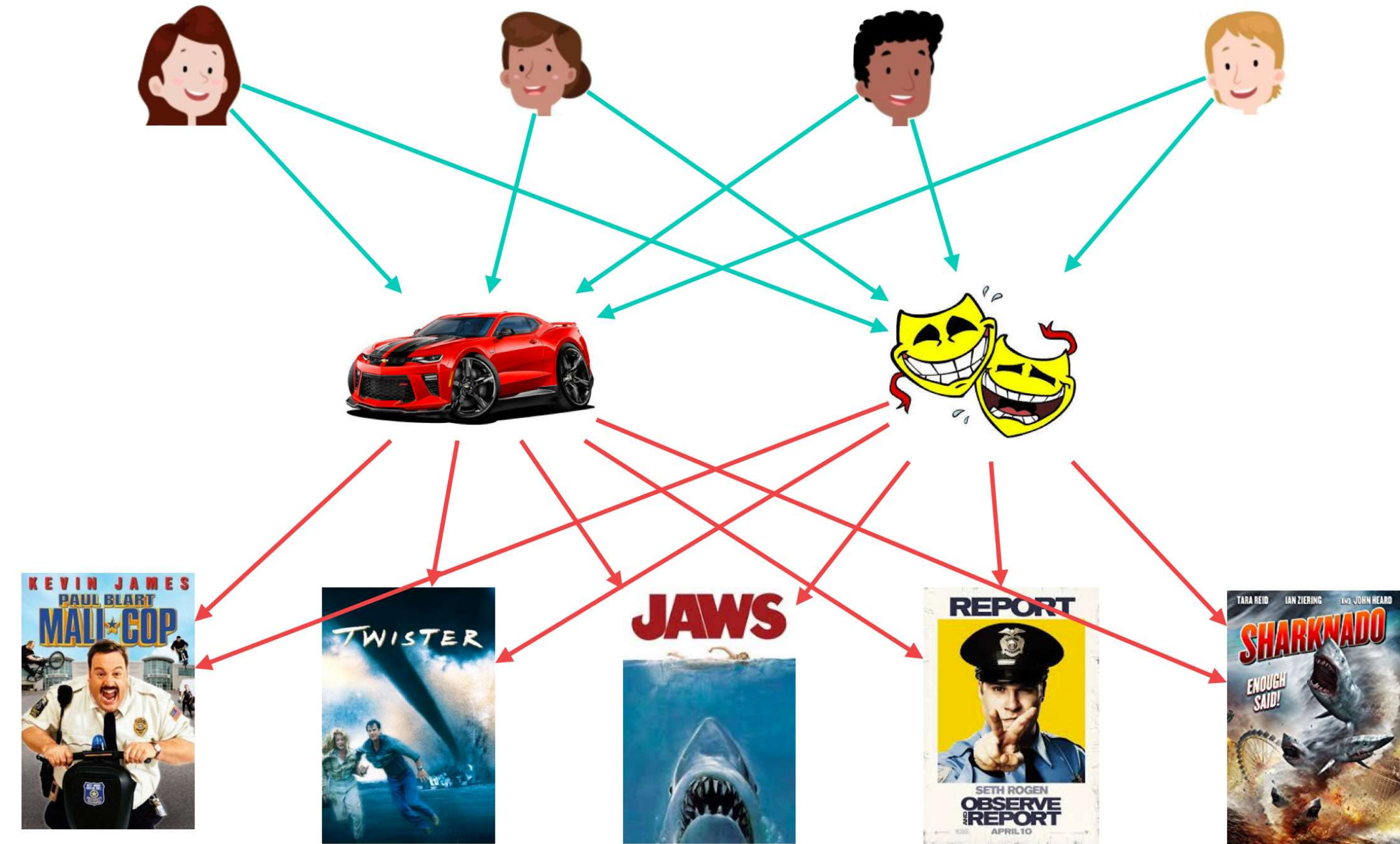




# Storage?



2M parameters

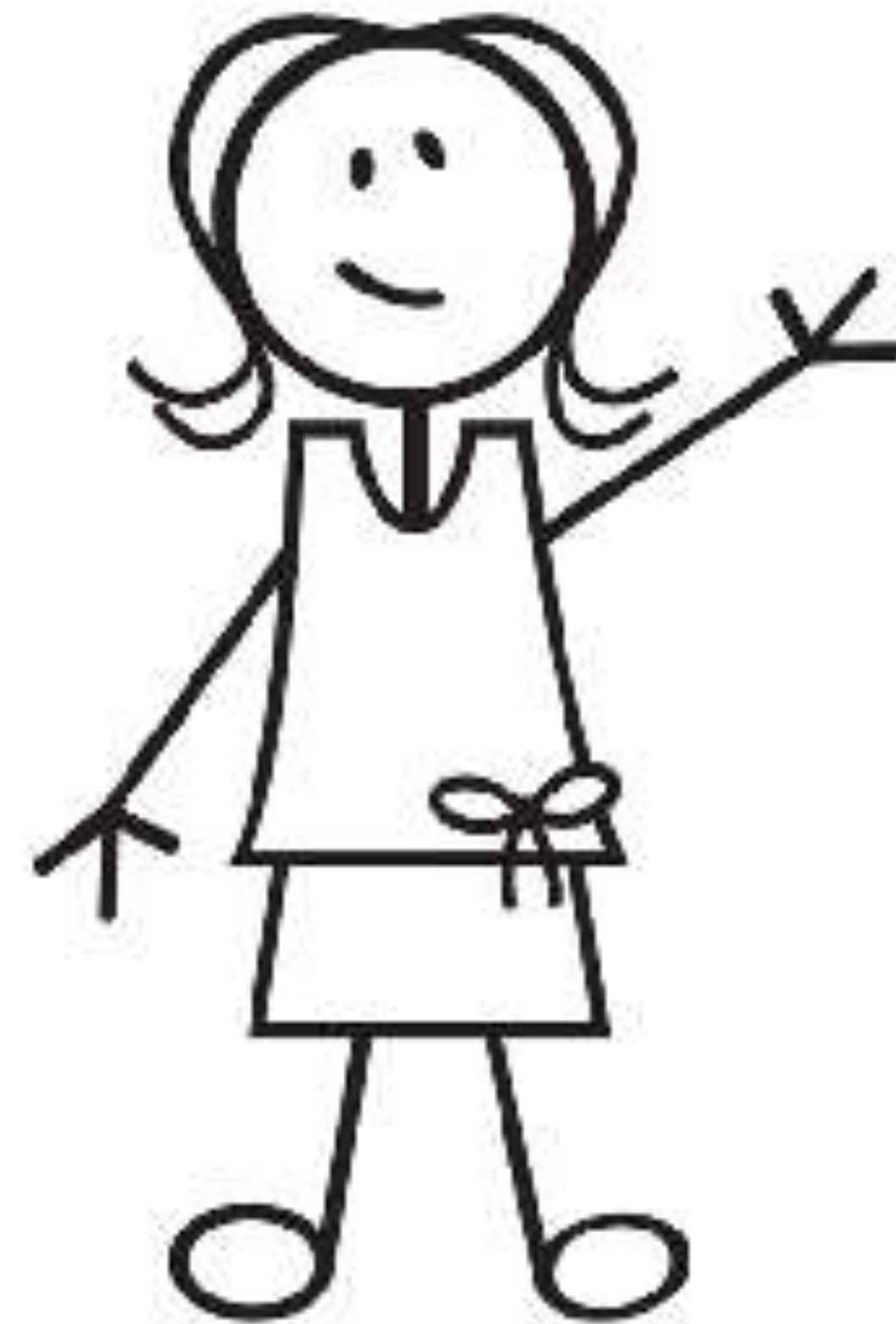
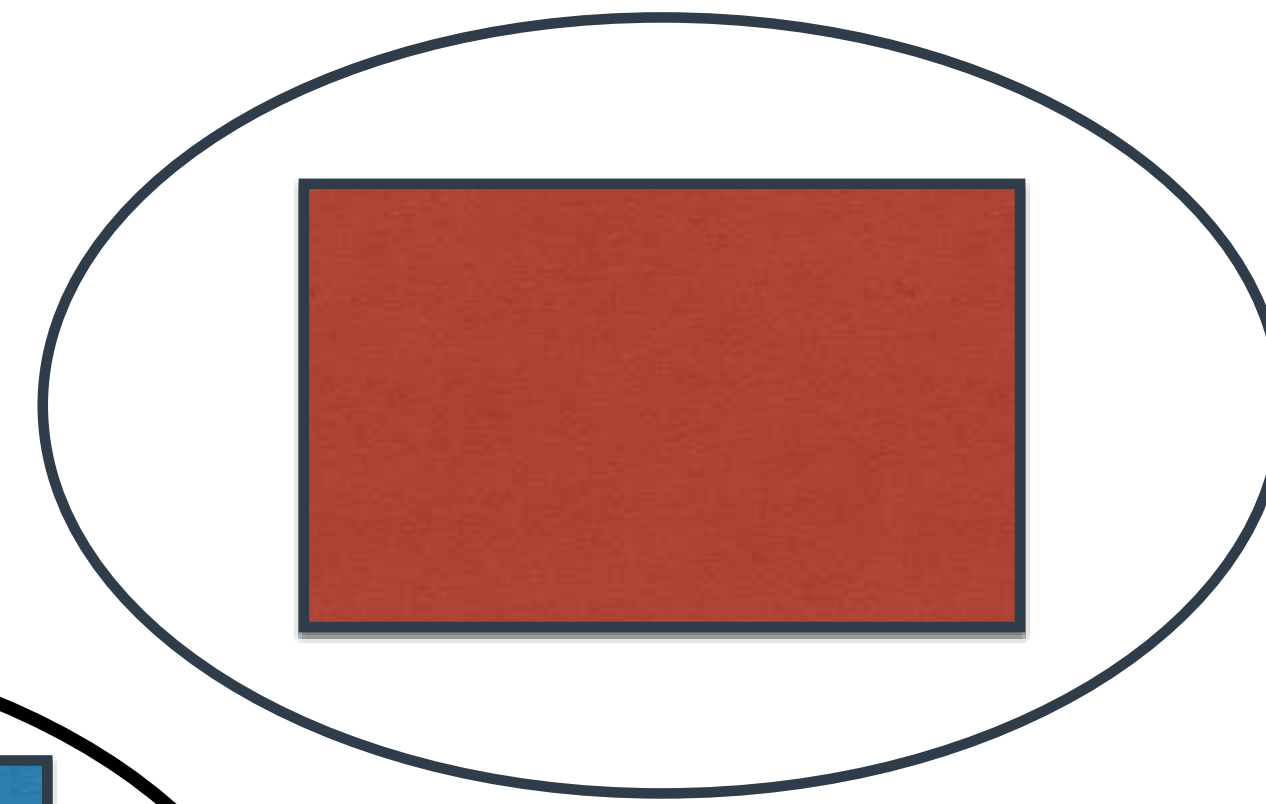
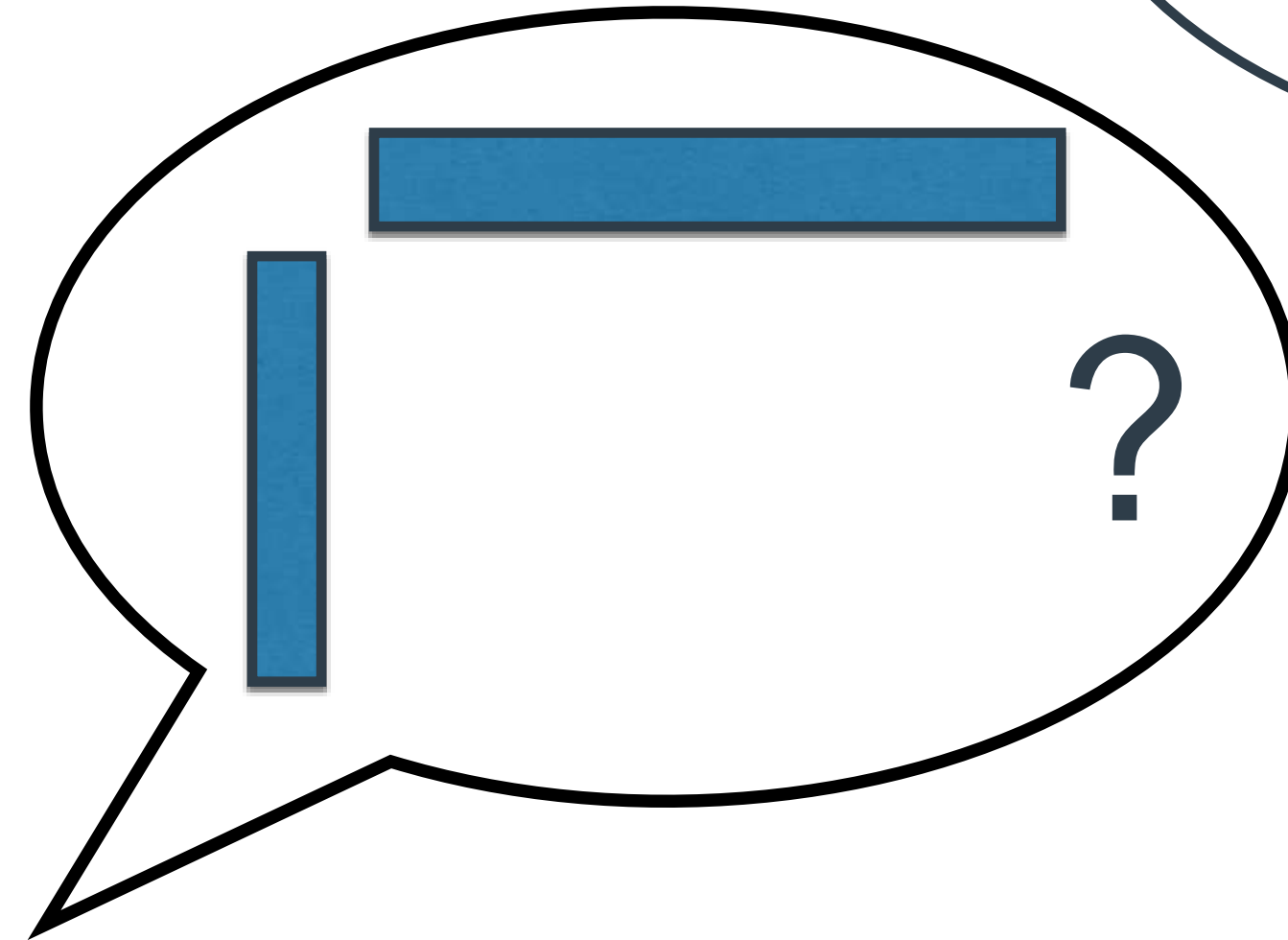


300K parameters

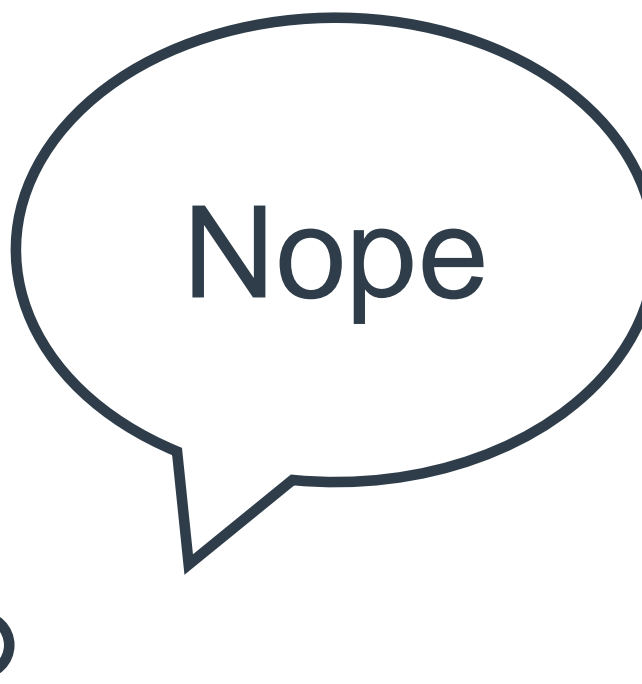
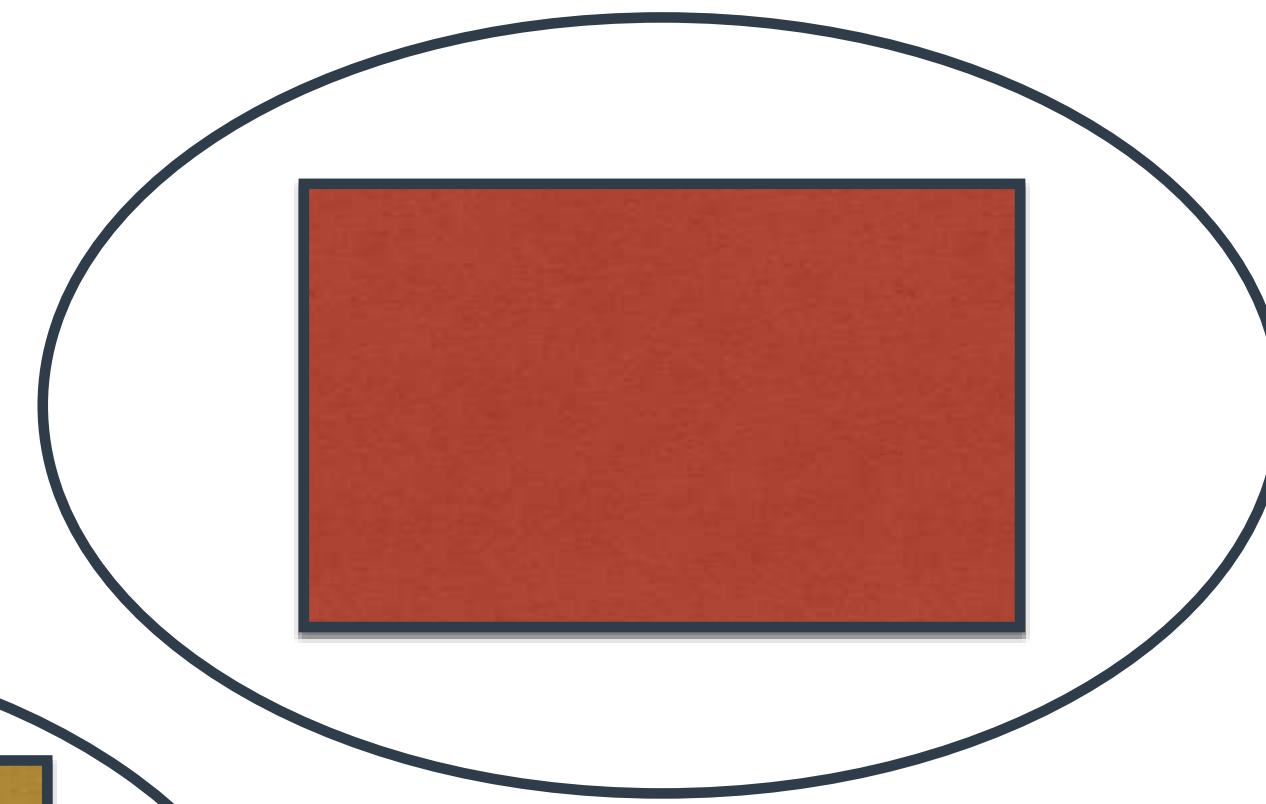
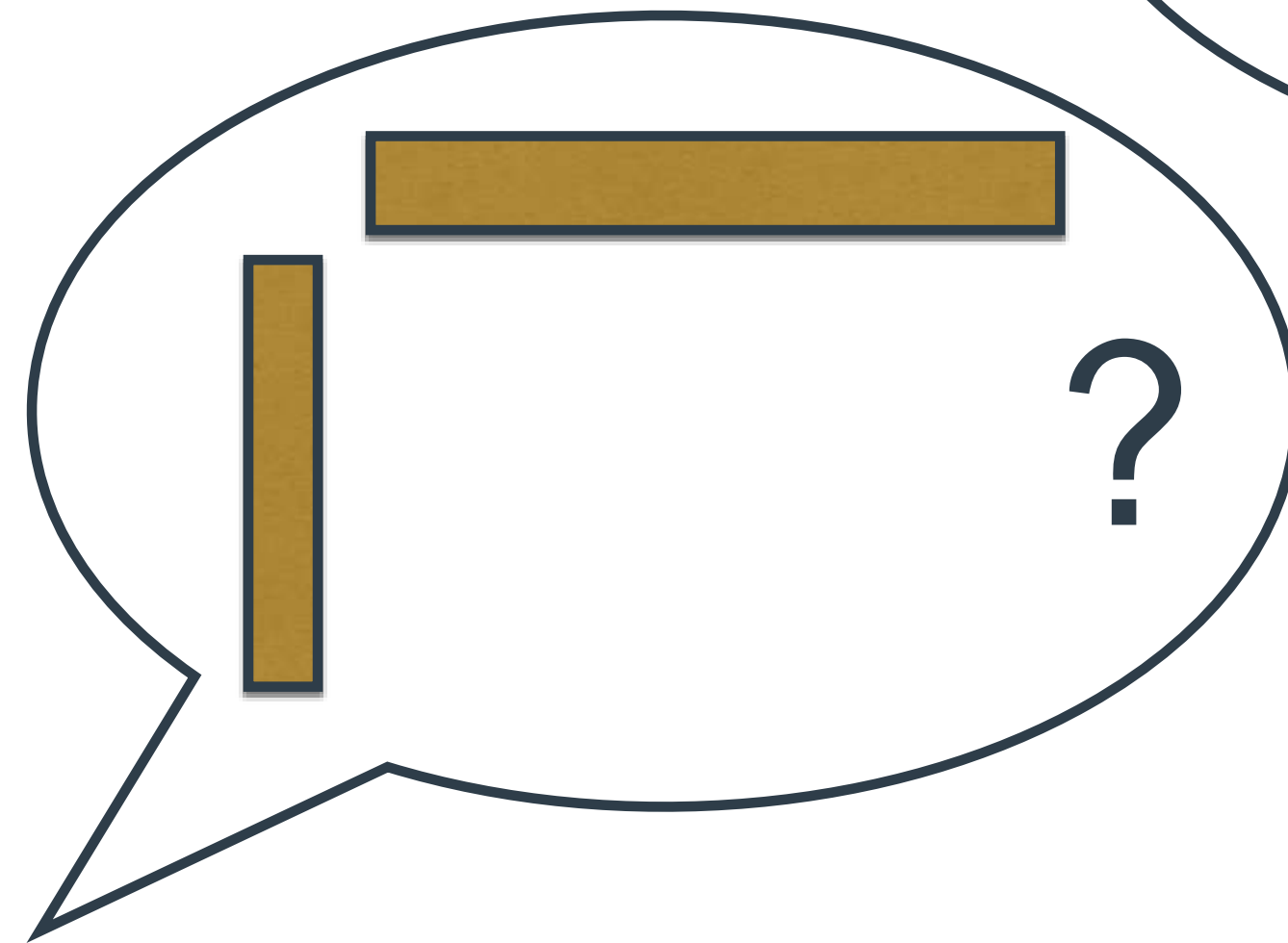
How to find the right factorization?



# Training models

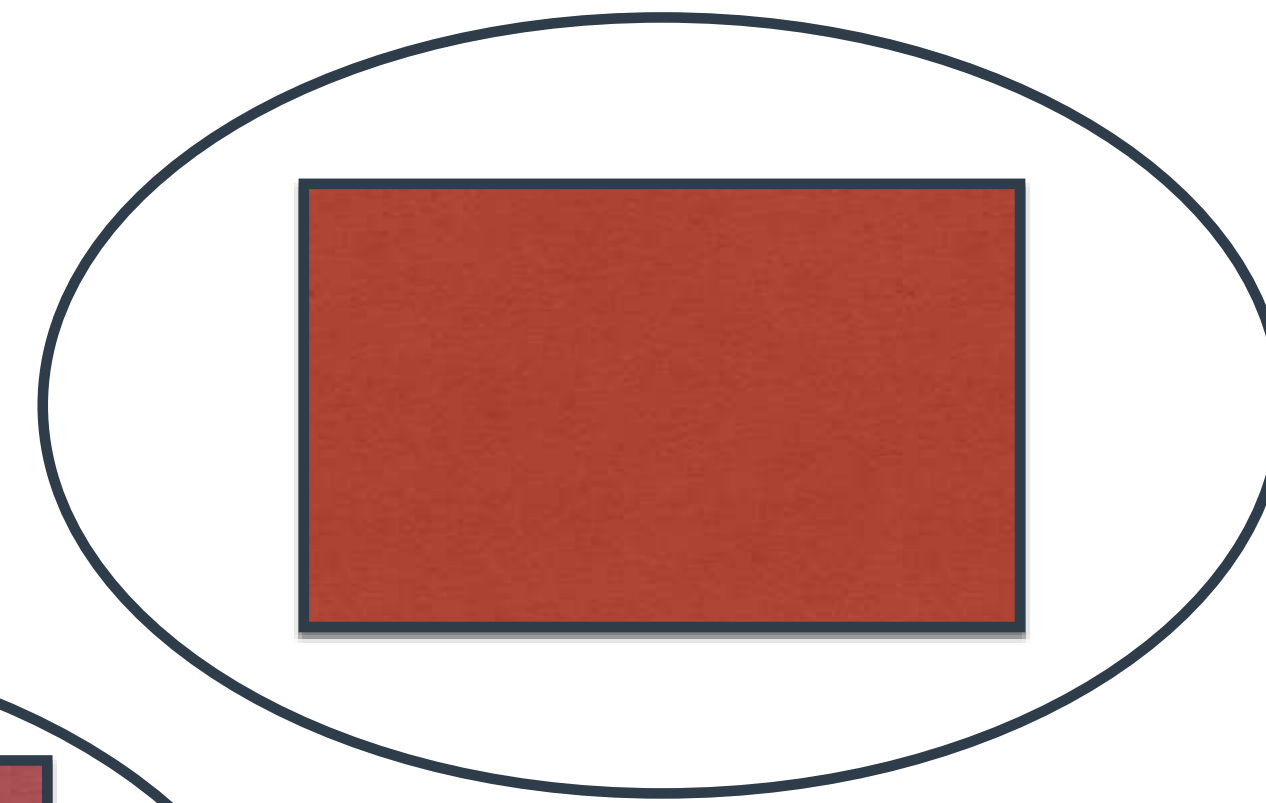
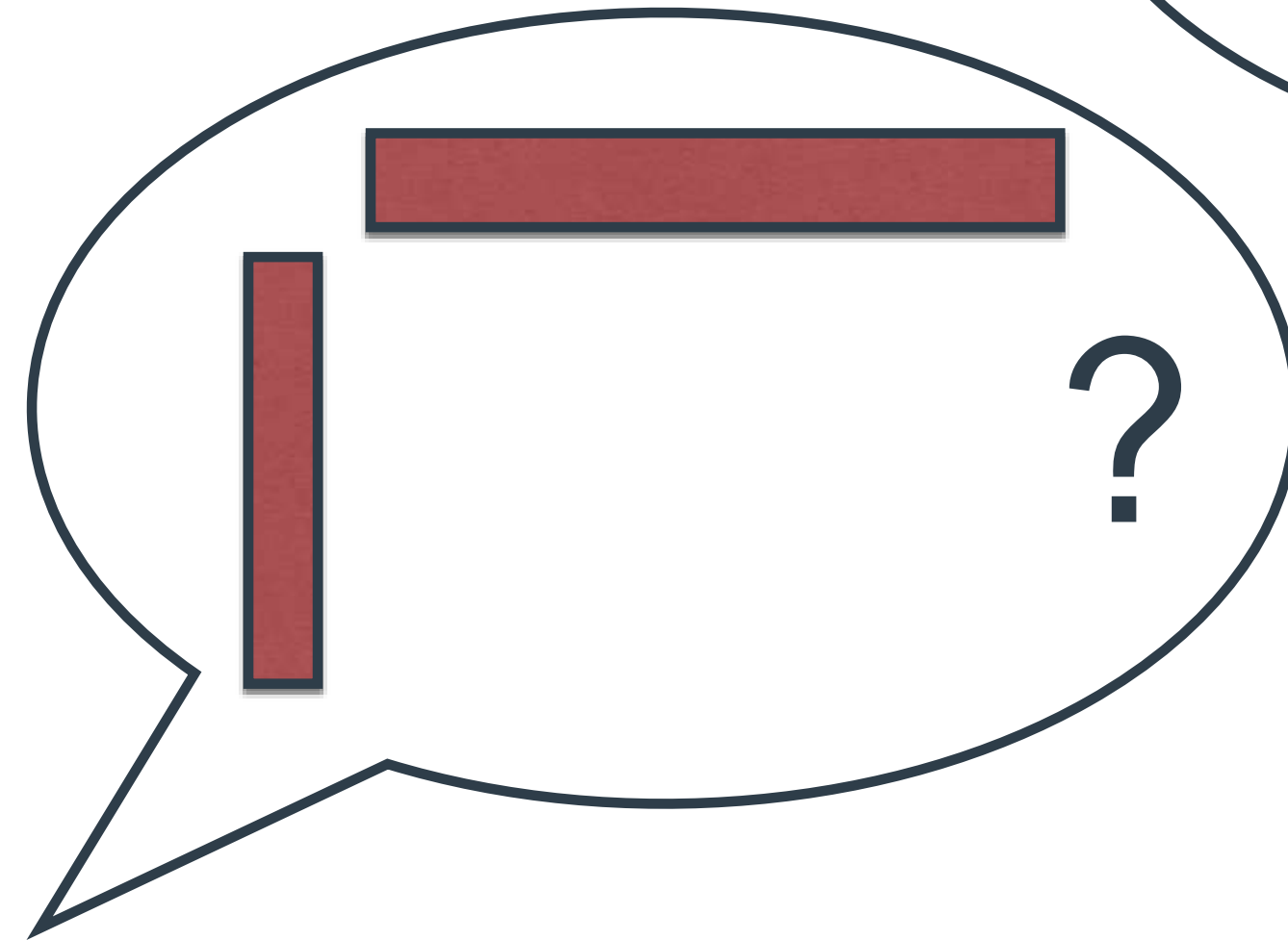


# Training models







# Training models



# Gradient Descent



# Matrix Factorization







	M1	M2	M3	M4	M5
 Comedy	3	1	1	3	1
 Action	1	2	4	1	3




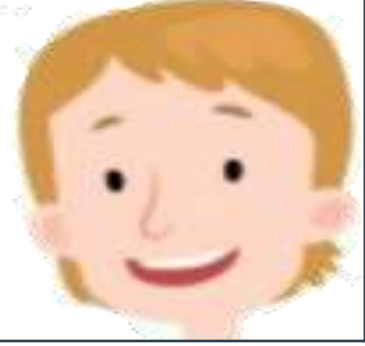


1







0





	 Comedy	 Action
 A	1	0
 B	0	1
 C	1	0
 D	1	1

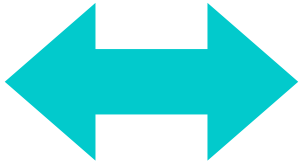
	M1	M2	M3	M4	M5
	3	1	1	3	1
	1	2	4	1	3
	3	1	1	3	1
	4	3	5	4	4





	M1	M2	M3	M4	M5
F1	1.2	3.1	0.3	2.5	0.2
F2	2.4	1.5	4.4	0.4	1.1

$$1.2 \times 0.2 + 2.4 \times 0.5 = 1.44$$

	F1	F2
 A	0.2	0.5
 B	0.3	0.4
 C	0.7	0.8
 D	0.4	0.5


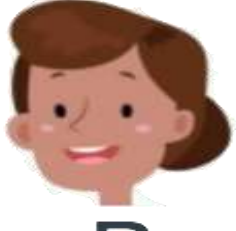


	M1	M2	M3	M4	M5
	1.44	1.37	2.26	0.7	0.59
	1.32	1.53	1.85	0.91	0.5
	2.76	3.37	3.73	2.07	1.02
	1.68	1.99	2.32	1.2	0.63







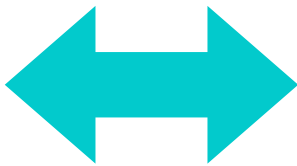
	M1	M2	M3	M4	M5
	3	1	1	3	1
	1	2	4	1	3
	3	1	1	3	1
	4	3	5	4	4







	M1	M2	M3	M4	M5
F1	1.2	3.1	0.3	2.5	0.2
F2	2.4	1.5	4.4	0.4	1.1

	F1	F2
 A	0.2	0.5
 B	0.3	0.4
 C	0.7	0.8
 D	0.4	0.5

	M1	M2	M3	M4	M5
	1.44	1.37	2.26	0.7	0.59
	1.32	1.53	1.85	0.91	0.5
	2.76	3.37	3.73	2.07	1.02
	1.68	1.99	2.32	1.2	0.63



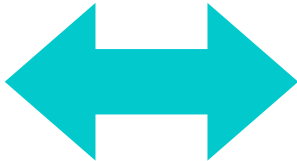
	M1	M2	M3	M4	M5
	3	1	1	3	1
	1	2	4	1	3
	3	1	1	3	1
	4	3	5	4	4

	M1	M2	M3	M4	M5
F1	1.2	3.1	0.3	2.5	0.2
F2	2.4	1.5	4.4	0.4	1.1

$1.2 \times 0.2 + 2.4 \times 0.5 = 1.44$

	F1	F2
A	0.2	0.5
B	0.3	0.4
C	0.7	0.8
D	0.4	0.5

	M1	M2	M3	M4	M5
A	1.44				
B					
C					
D					



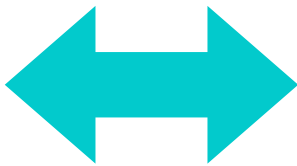
	M1	M2	M3	M4	M5
A	3	1	1	3	1
B	1	2	4	1	3
C	3	1	1	3	1
D	4	3	5	4	4



	M1	M2	M3	M4	M5
F1	1.1	3.1	0.3	2.5	0.2
F2	2.5	1.5	4.4	0.4	1.1

	F1	F2
A	0.3	0.6
B	0.3	0.4
C	0.7	0.8
D	0.4	0.5

	M1	M2	M3	M4	M5
A					
B					
C					
D					



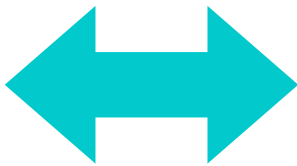
	M1	M2	M3	M4	M5
A	3	1	1	3	1
B	1	2	4	1	3
C	3	1	1	3	1
D	4	3	5	4	4

	M1	M2	M3	M4	M5
F1	1.4	3.1	0.3	2.5	0.2
F2	2.5	1.5	4.4	0.4	1.1

$1.4 \times 0.3 + 2.5 \times 0.6 = 1.92$

	F1	F2
A	0.3	0.6
B	0.3	0.4
C	0.7	0.8
D	0.4	0.5

	M1	M2	M3	M4	M5
A	1.92				
B					
C					
D					



	M1	M2	M3	M4	M5
A	3	1	1	3	1
B	1	2	4	1	3
C	3	1	1	3	1
D	4	3	5	4	4

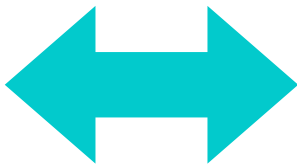


	M1	M2	M3	M4	M5
F1	1.4	3.1	0.3	2.5	0.2
F2	2.5	1.5	4.4	0.4	1.1

$$1.4 \times 0.3 + 2.5 \times 0.6 = 1.92$$

	F1	F2
A	0.3	0.6
B	0.3	0.4
C	0.7	0.8
D	0.4	0.5

	M1	M2	M3	M4	M5
A	1.92	1.83			
B					
C					
D					







	M1	M2	M3	M4	M5
A	3	1	1	3	1
B	1	2	4	1	3
C	3	1	1	3	1
D	4	3	5	4	4





	M1	M2	M3	M4	M5
F1	1.4	3.1	0.3	2.5	0.2
F2	2.5	1.5	4.4	0.4	1.1

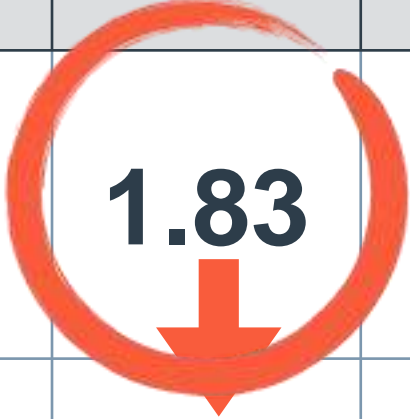






$3.1 \times 0.3 + 1.5 \times 0.6 = 1.83$

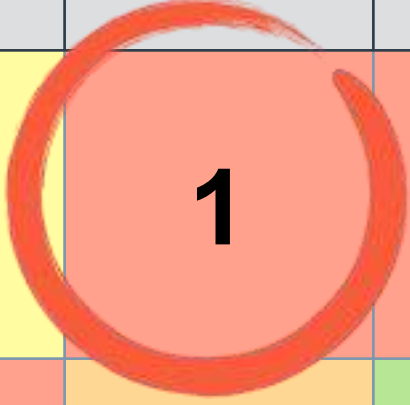
	F1	F2
 A	0.3	0.6
 B	0.3	0.4
 C	0.7	0.8
 D	0.4	0.5



	M1	M2	M3	M4	M5
	1.92	1.83			
					
					
					



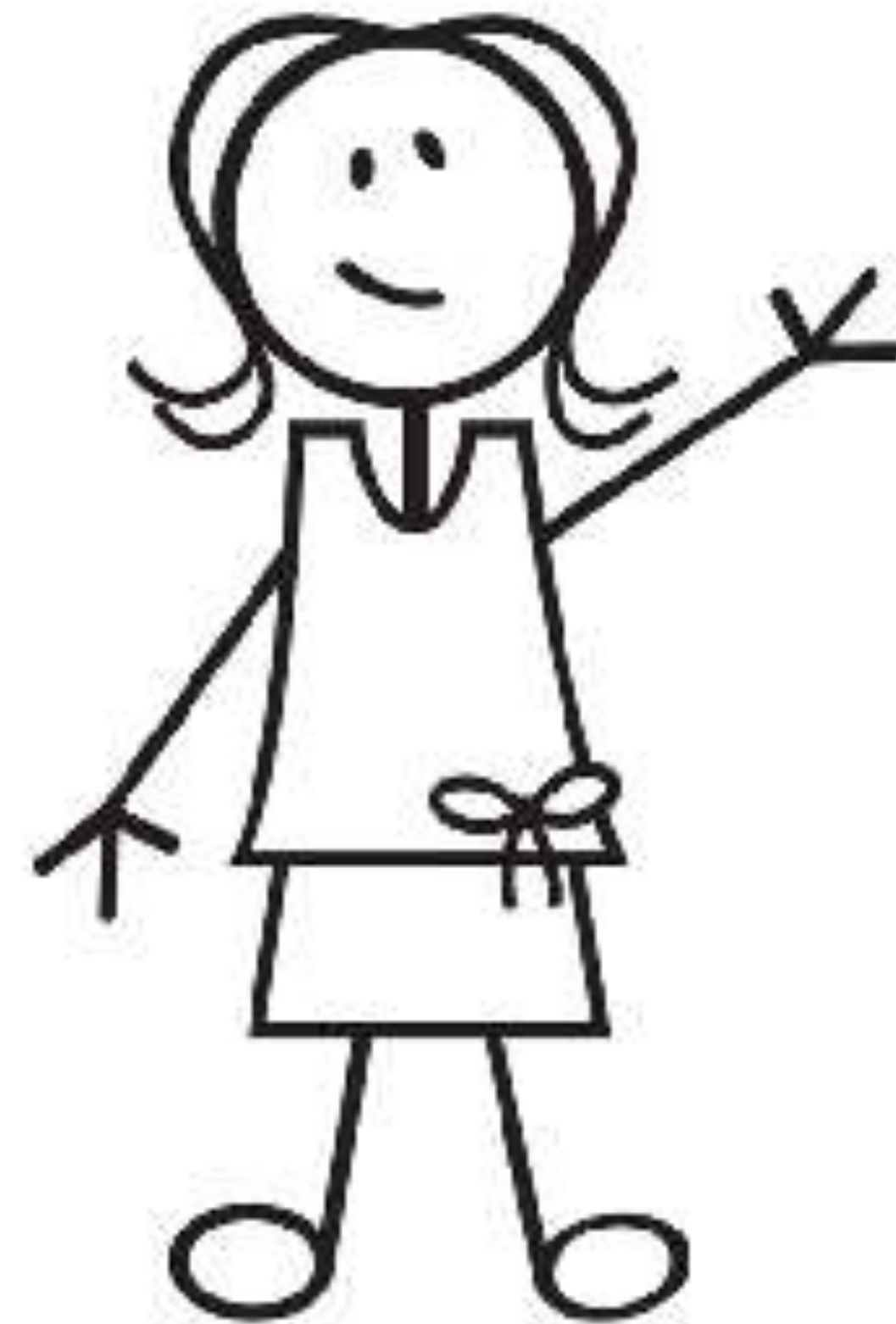
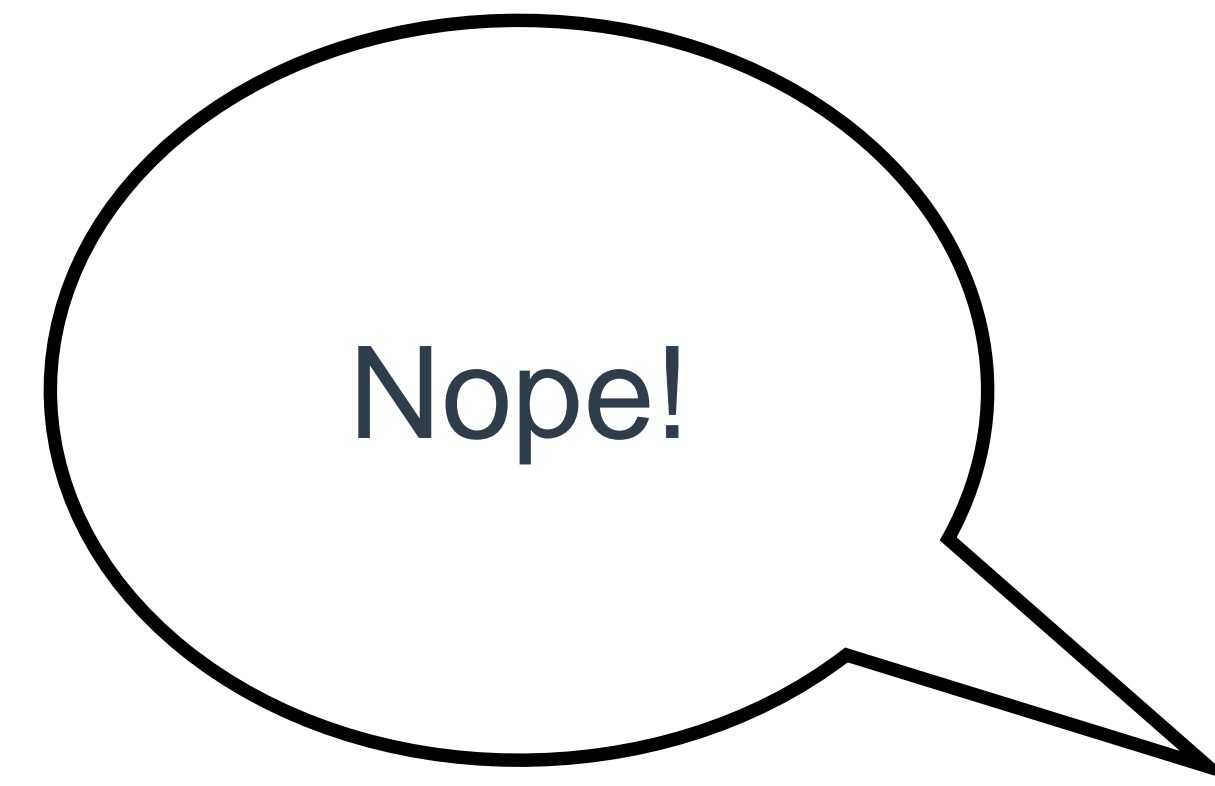
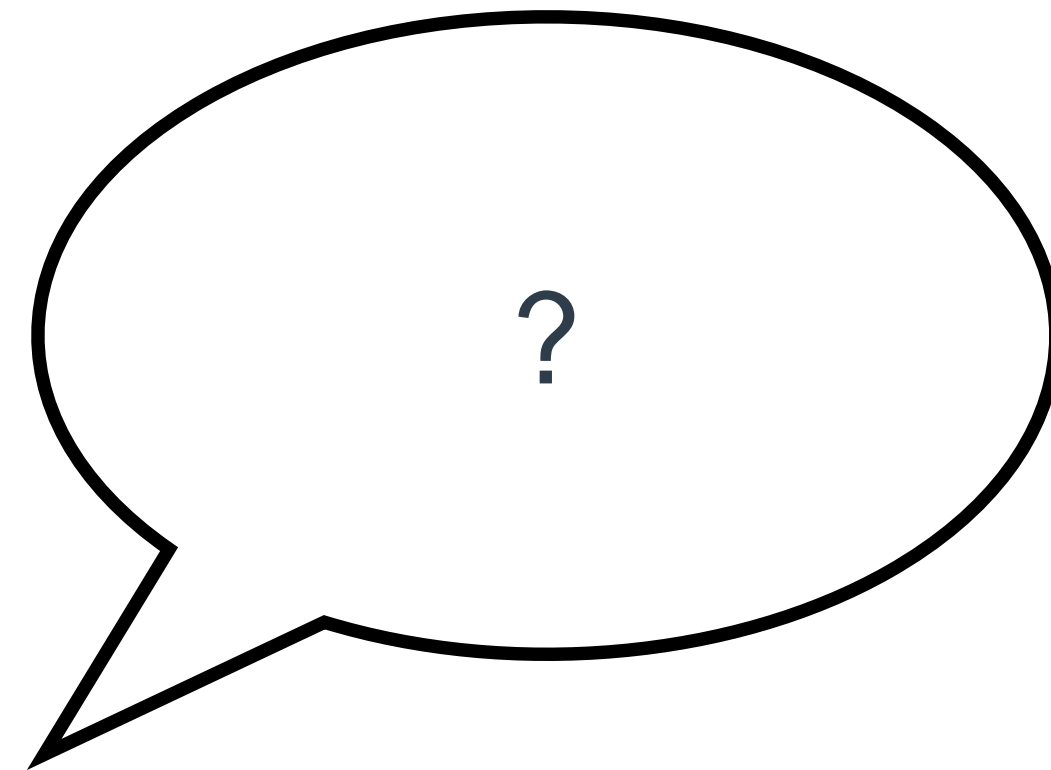
	M1	M2	M3	M4	M5
	3	1	1	3	1
	1	2	4	1	3
	3	1	1	3	1
	4	3	5	4	4





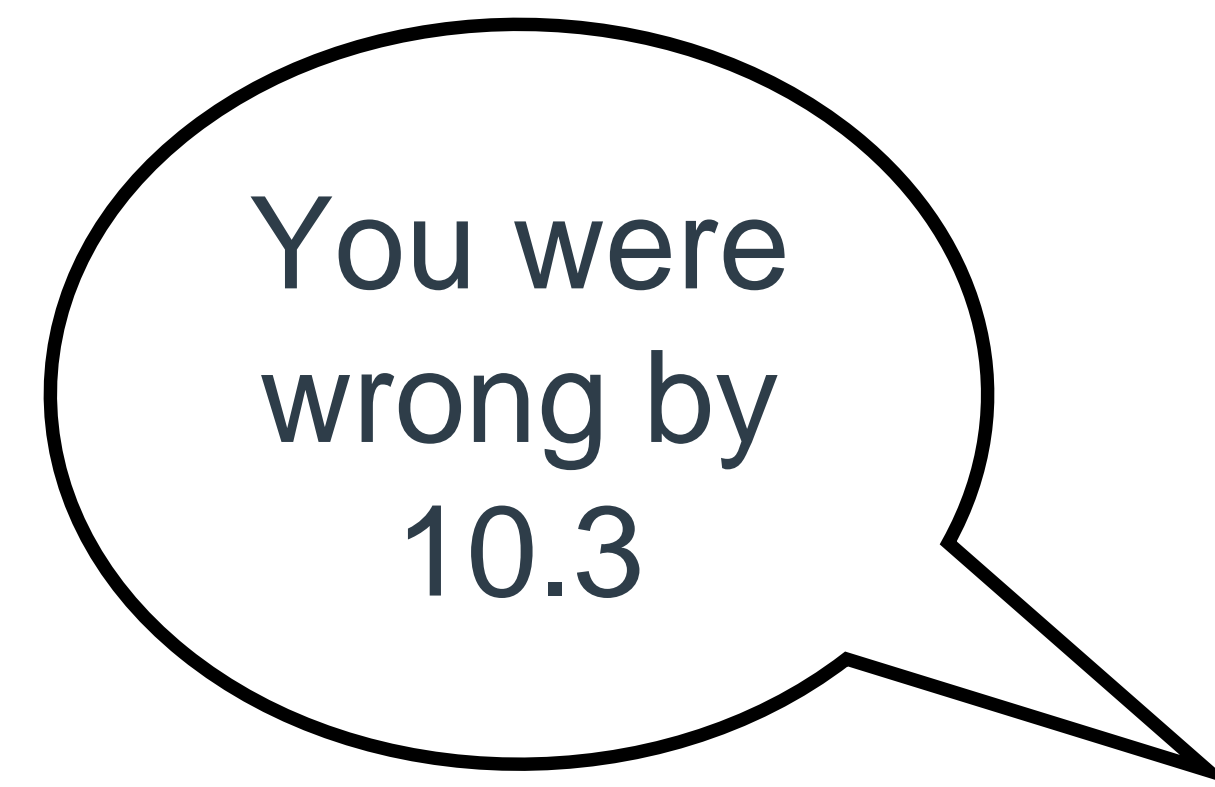
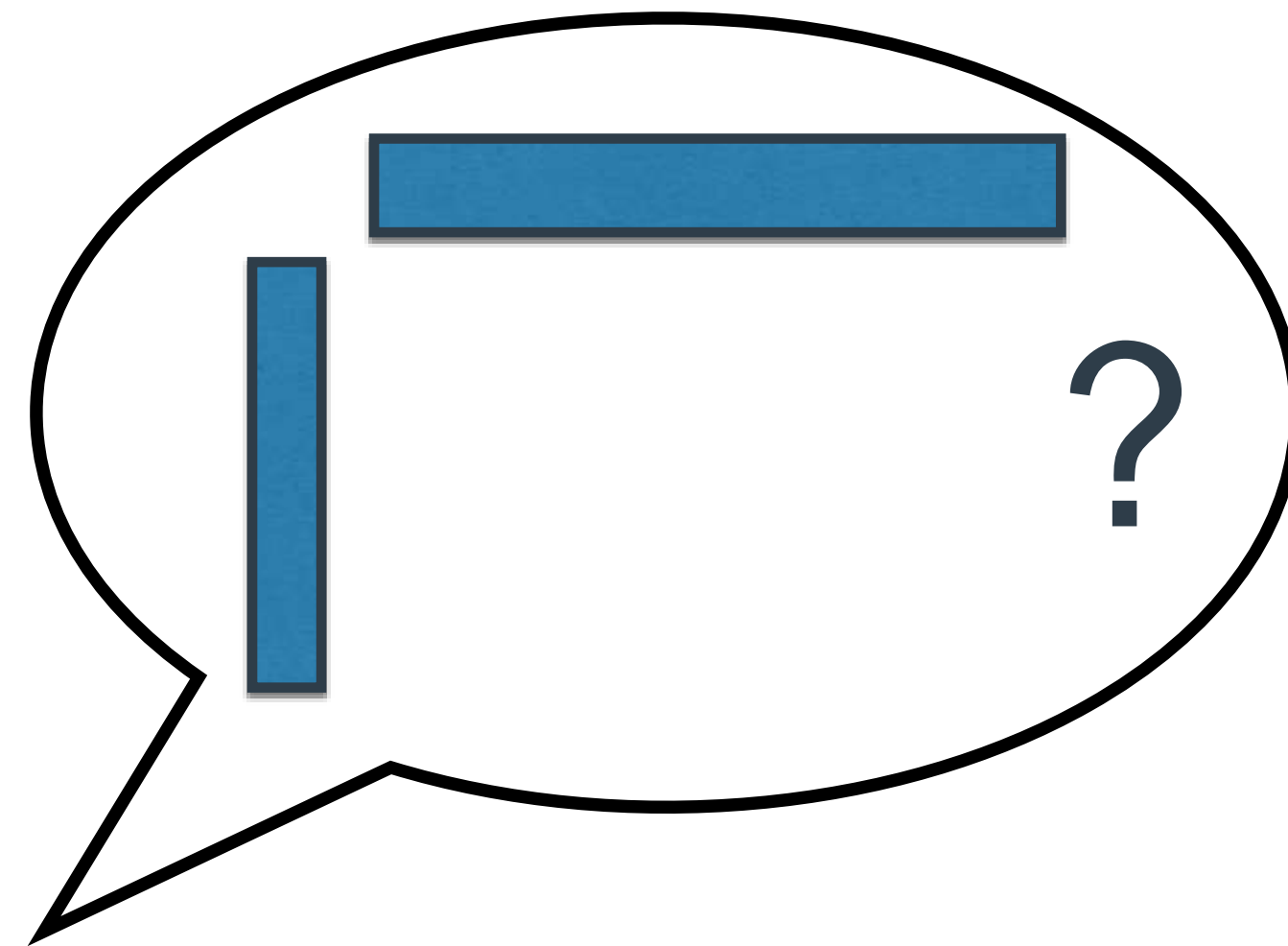
# Error function

# Training models

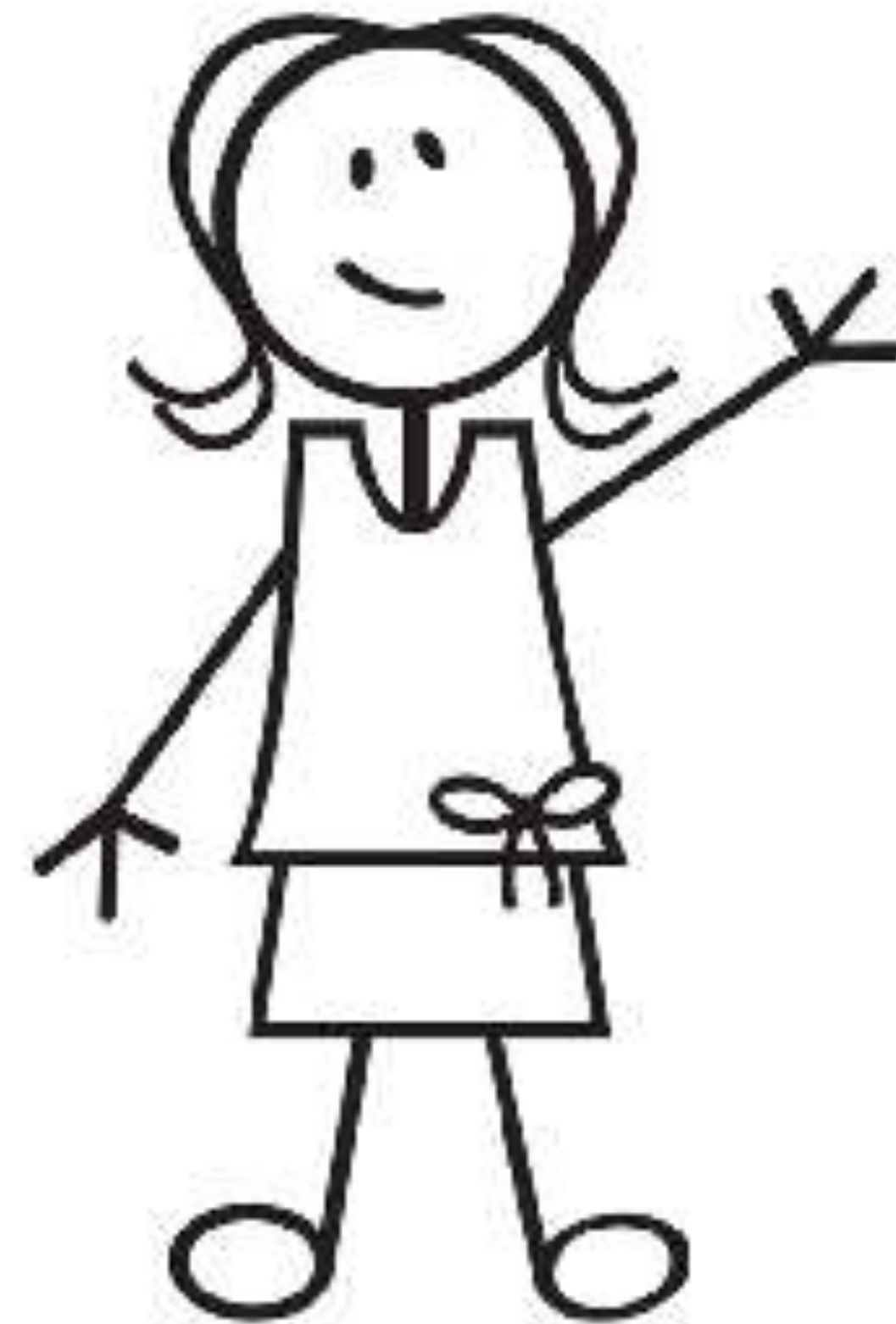
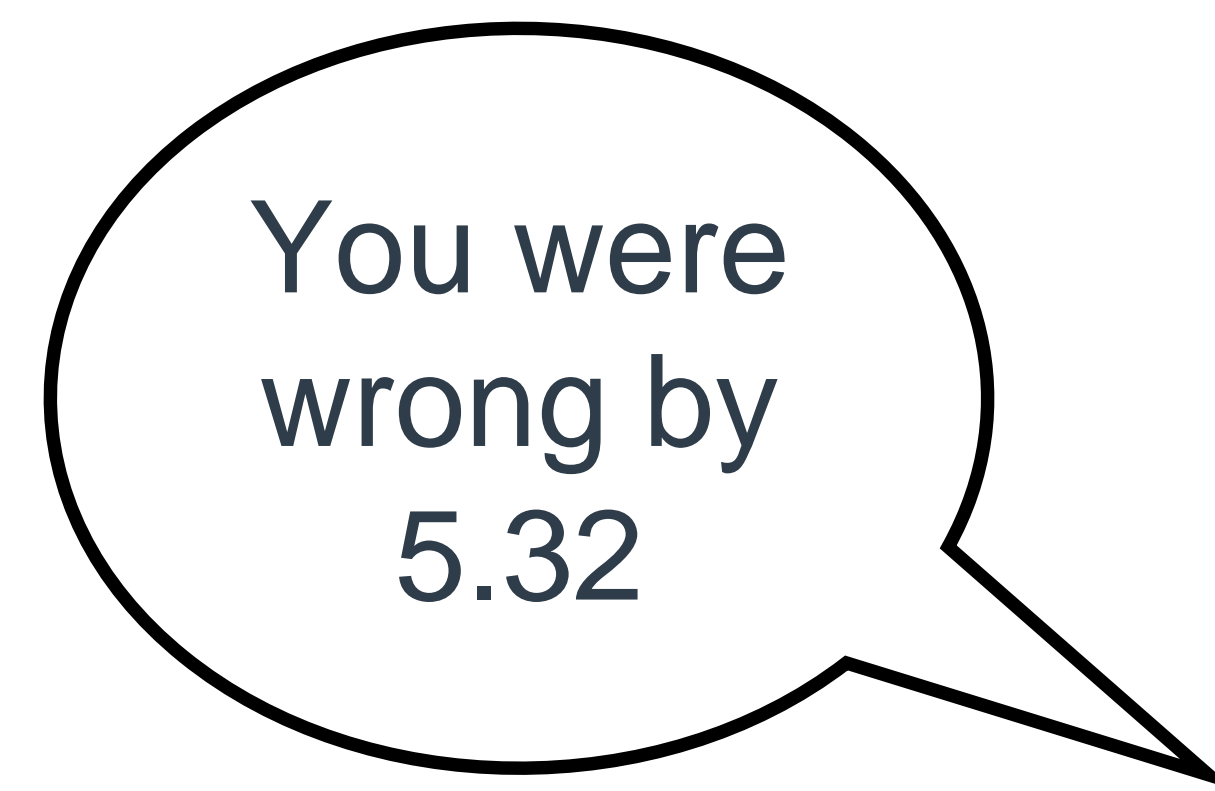
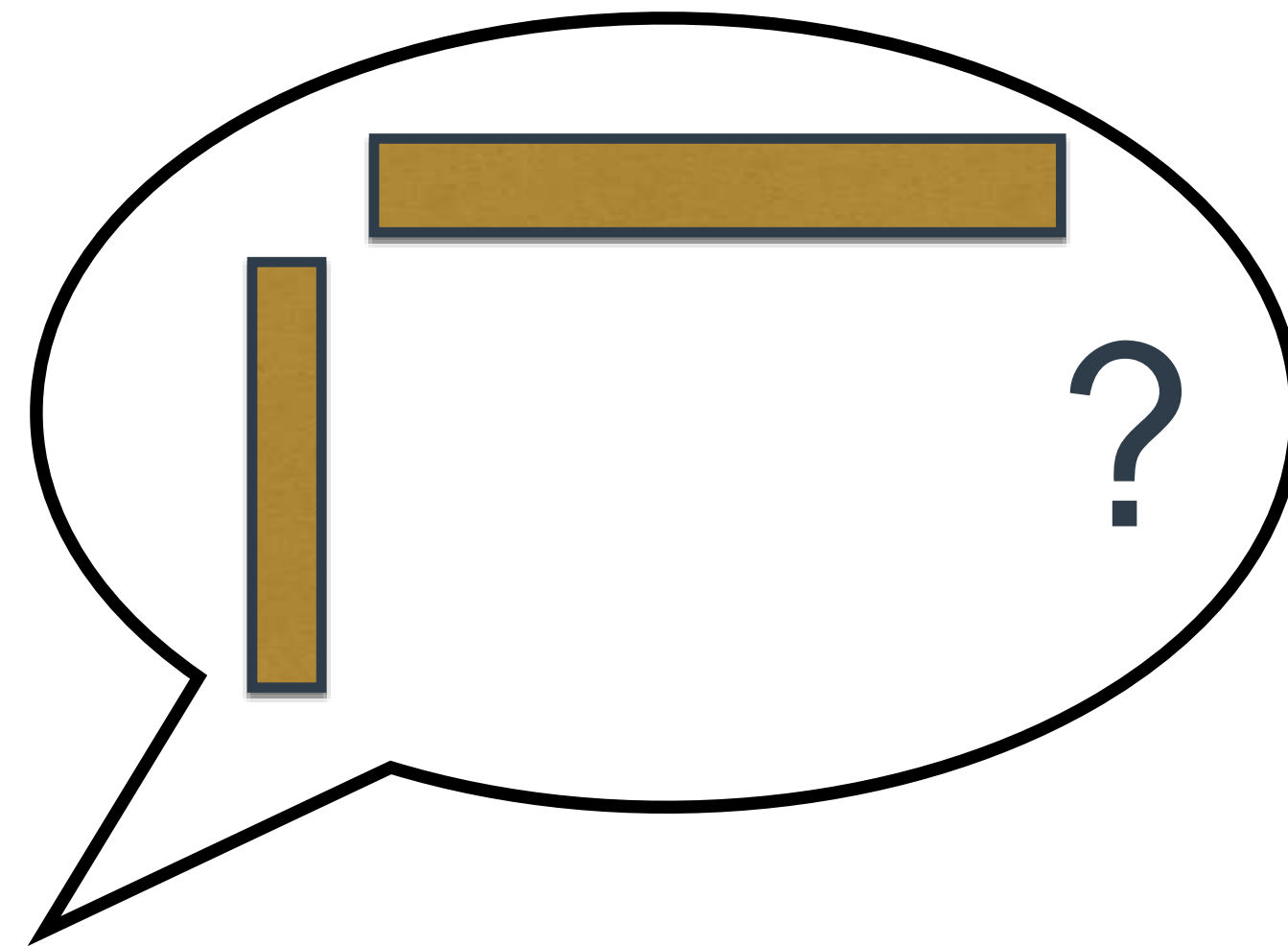




# Training models

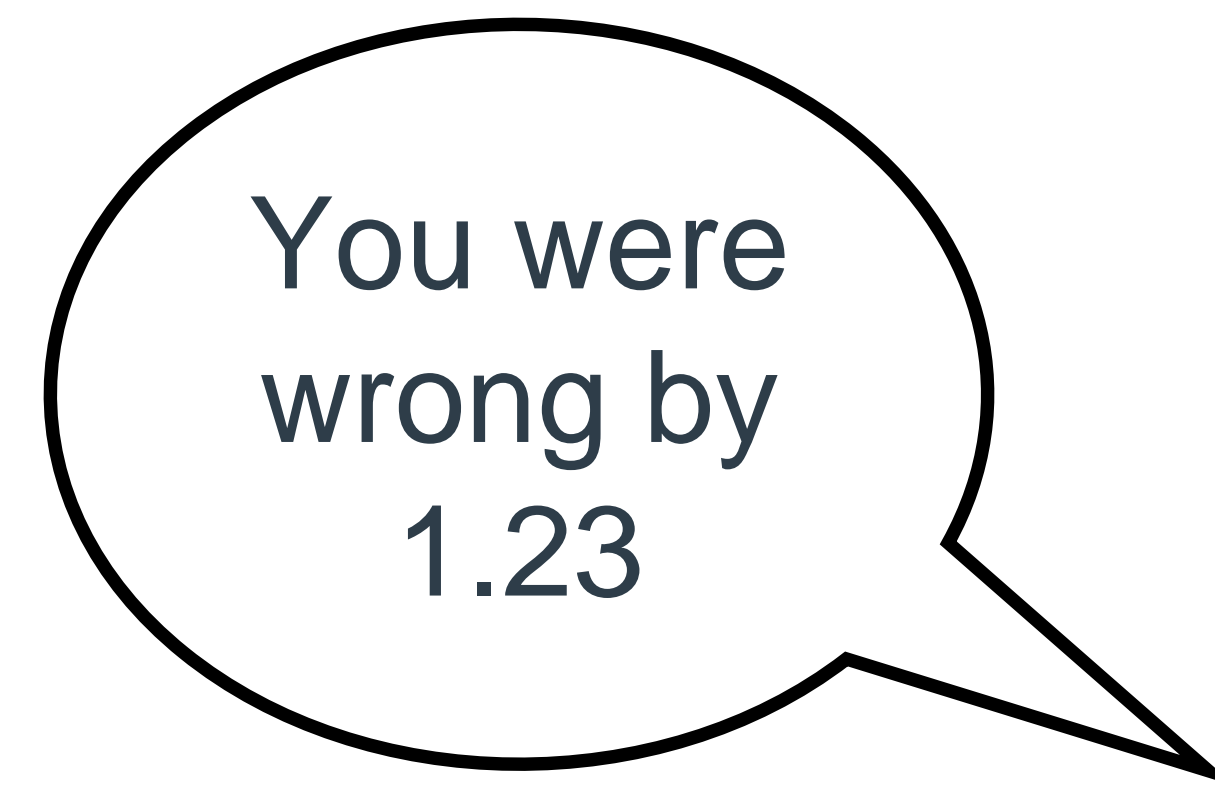
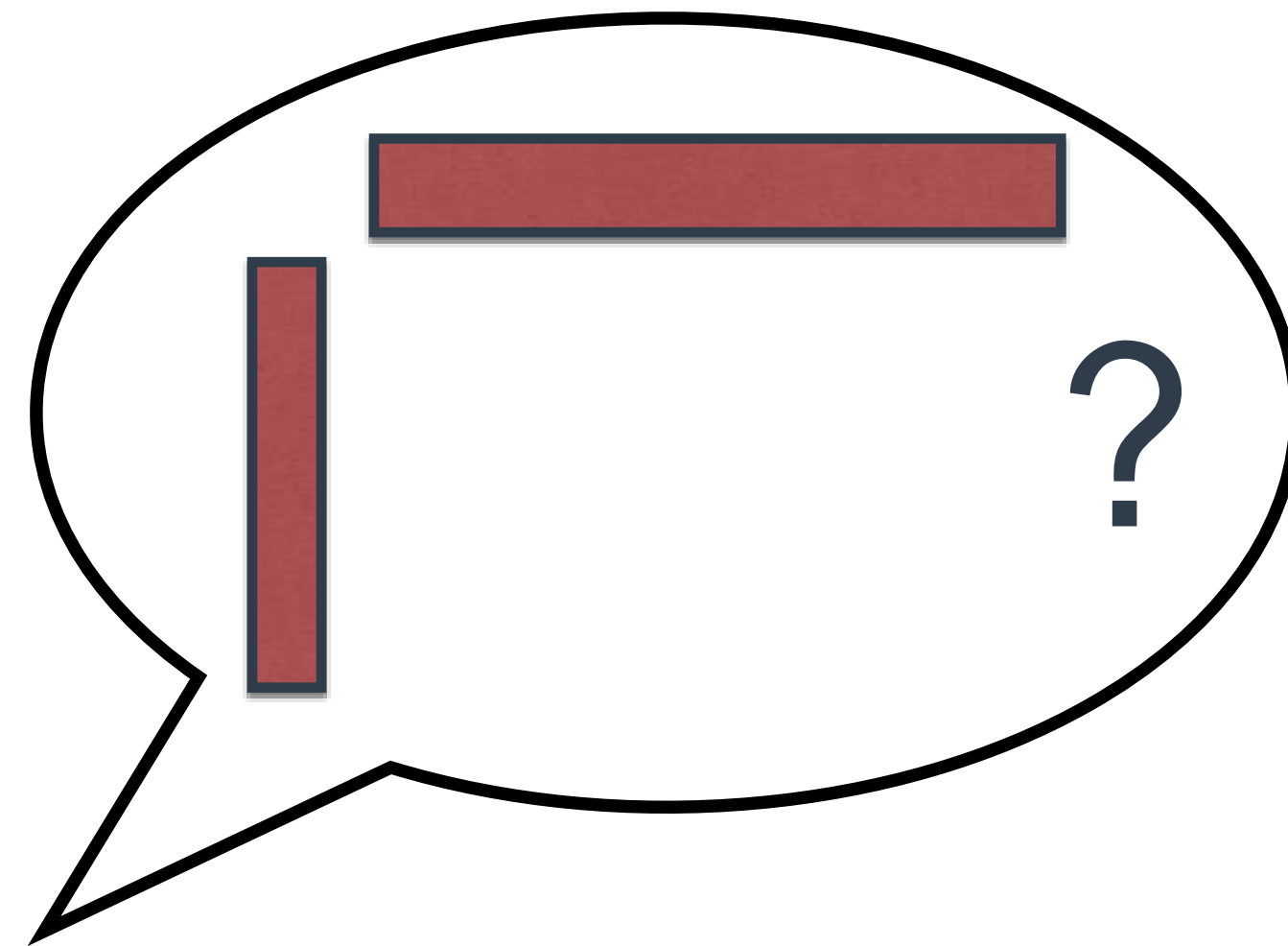


# Training models
















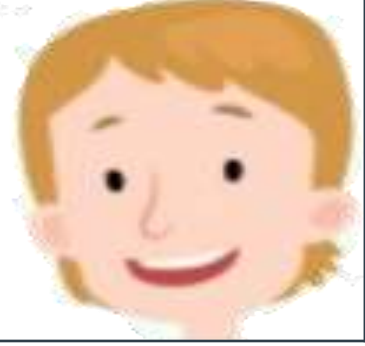
# Training models



# Matrix Factorization

	M1	M2	M3	M4	M5
 Comedy	3	1	1	3	1
 Action	1	2	4	1	3

	 Comedy	 Action
 A	1	0
 B	0	1
 C	1	0
 D	1	1





	M1	M2	M3	M4	M5
	3	1	1	3	1
	1	2	4	1	3
	3	1	1	3	1
	4	3	5	4	4







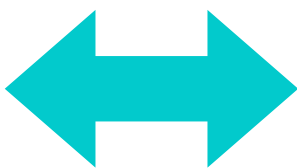
# Error Function





	M1	M2	M3	M4	M5
F1	1.2	3.1	0.3	2.5	0.2
F2	2.4	1.5	4.4	0.4	1.1

Error =  $(3 - 1.44)^2$

	F1	F2
 A	0.2	0.5
 B	0.3	0.4
 C	0.7	0.8
 D	0.4	0.5





	M1	M2	M3	M4	M5
	1.44				
					
					
					







	M1	M2	M3	M4	M5
	3	1	1	3	1
	1	2	4	1	3
	3	1	1	3	1
	4	3	5	4	4

# Error Function

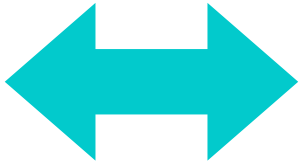
	M1	M2	M3	M4	M5
F1	1.2	1.1	0.3	2.5	0.2
F2	2.4	1.5	4.4	0.4	1.1





	F1	F2
 A	0.2	0.5
 B	0.3	0.4
 C	0.7	0.8
 D	0.4	0.5

	M1	M2	M3	M4	M5
	1.44	1.37			
					
					
					

Derivative  $\nearrow$

$$\text{Error} = (3 - 1.44)^2 + (1 - 1.37)^2 + \dots$$











	M1	M2	M3	M4	M5
	3	1	1	3	1
	1	2	4	1	3
	3	1	1	3	1
	4	3	5	4	4



Summary: How to use this?

	M1	M2	M3	M4	M5
F1	3	1	1	3	1
F2	1	2	4	1	3

	F1	F2
 A	1	0
 B	0	1
 C	1	0
 D	1	1

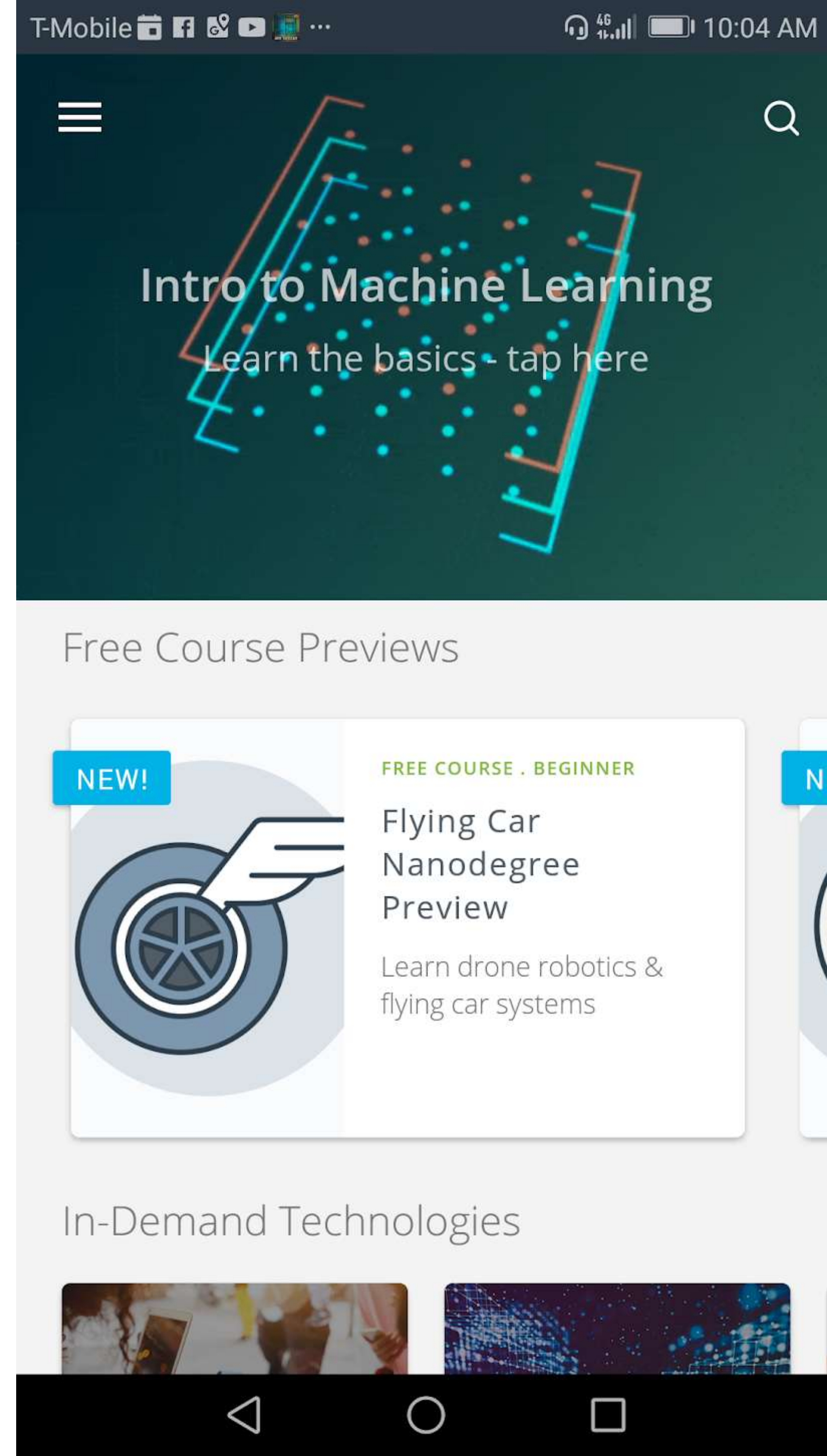
	M1	M2	M3	M4	M5
 A	3	1	1	3	1
 B	1	2	4	1	3
 C	3	1	1	3	1
 D	4	3	5	4	4



D

M3





# Thank you!

**Luis Serrano**

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[www.youtube.com/c/LuisSerrano](http://www.youtube.com/c/LuisSerrano)

[luisguiserrano.github.io](http://luisguiserrano.github.io)



[www.udacity.com](http://www.udacity.com)



