

Lecture 12: Advanced Data Mining Topics: Deep Learning, Recommender Systems, Social Networks

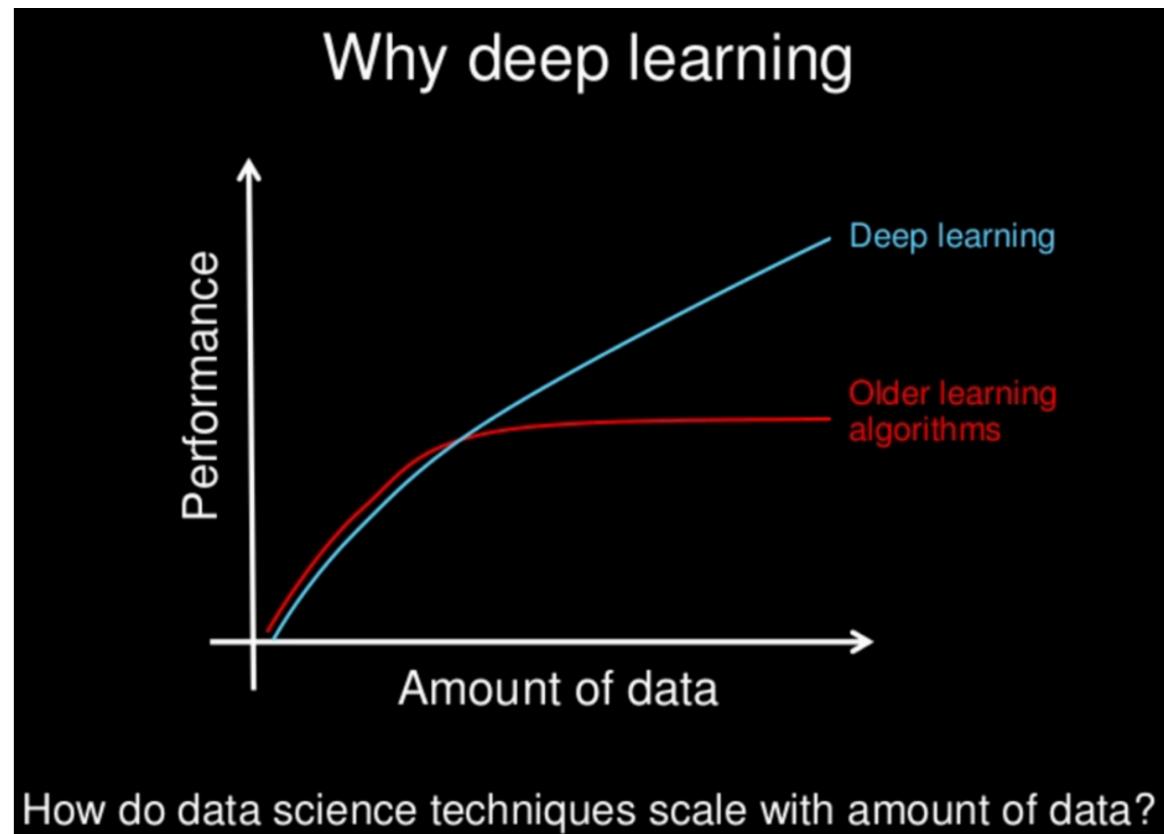
Deep Learning

Deep learning (also known as deep structured learning, hierarchical learning or deep machine learning) is a class of machine learning algorithms that:

- use a cascade of many layers of nonlinear processing units for feature extraction and transformation. Each successive layer uses the output from the previous layer as input.
- are based on the learning of multiple levels of features or representations of the data. Higher level features are derived from lower level features to form a hierarchical representation.
- are part of the broader machine learning field of learning representations of data.
- learn multiple levels of representations that correspond to different levels of abstraction; the levels form a hierarchy of concepts.

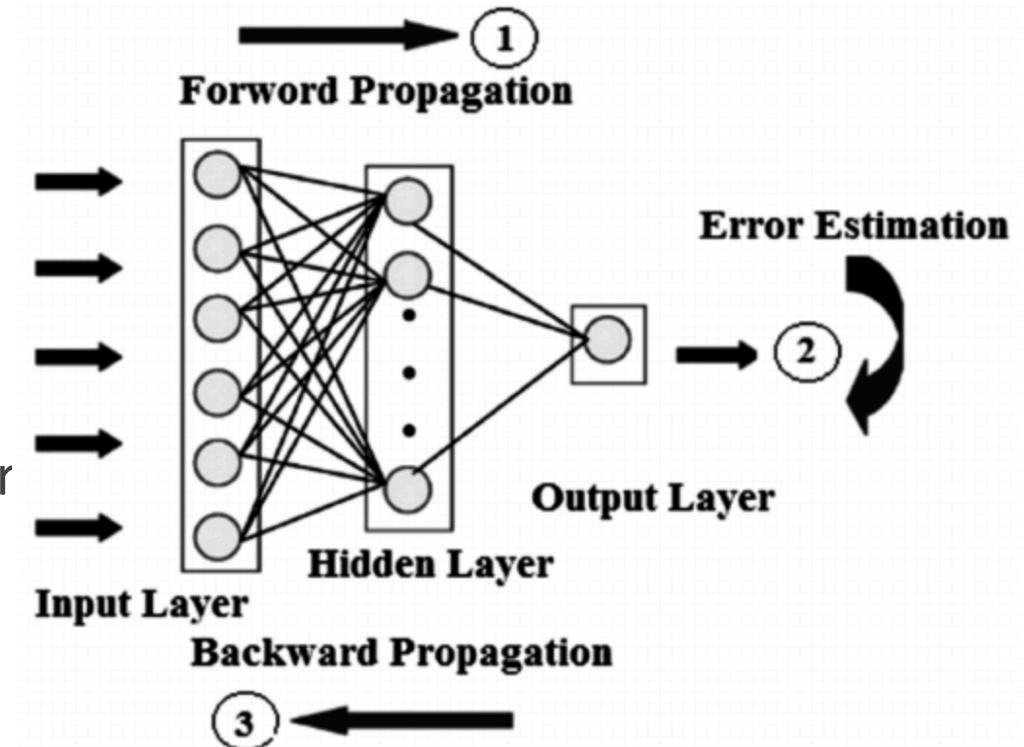
Why Deep Learning

- Advantages of deep learning:
 - Scalability (see picture)
 - Automatic feature selection
- Results get better with
 - More data
 - Bigger models
 - More computation



Principle of Deep Neural Networks

- **Feedforward and backward propagation**
- **Input x :** Set of input variables
- **Feedforward:** Information flows from the input layer to the output layer
- **Output error:** Compute the error with the cost function of the output value and real value
- **Backpropagate the error:** Calculate the error for each neuron from the output layer to the input layer
- **Update parameters:** Adjust the weight according to the backward propagation error



Deep Learning: Image Processing

Unlocking Value from Digital Assets with Image Content Categorization

■ *What Is Image Tagging?*

- Image tagging is the process of labeling or keywording images based on figures within a certain picture. It makes images on websites more searchable through keywords pertaining to that photo.
- Using Image tagging and categorization, we can add context to images.



Unlocking Value from Digital Assets with Image Content Categorization

How Companies Benefit From Image Tagging?

A company benefits from image tagging because of how quickly they organize images and how accessible their images become to users. When a user searches their website, they can find what they need based on simple keywords.



- In this image, the bigger words are stronger keywords and the smaller words are secondary.
- These were automatically sorted and ranked by an image tagging program.
- Without auto tagged metadata, these images can't be found. And if you can't find them, you can't use them.

Unlocking Value from Digital Assets with Image Content Categorization

■ Image classification

Photos for The Cheesecake Factory



Add photos

All (537) Food (453) Inside (29) Drink (20) Menu (8) Outside (7)

Search photos...



Self Driving Car

- Tesla may grant certain customers early access to a “feature complete” version of the company’s “full self-driving” (FSD) capabilities by the end of 2019.
- Musk says the car will be able to drive from someone’s home to their work without intervention.

How self-driving cars work?

- Self-driving cars combine a variety of sensors to perceive their surroundings.
- Advanced control systems interpret sensory information to identify appropriate navigation paths, as well as obstacles and relevant signage.

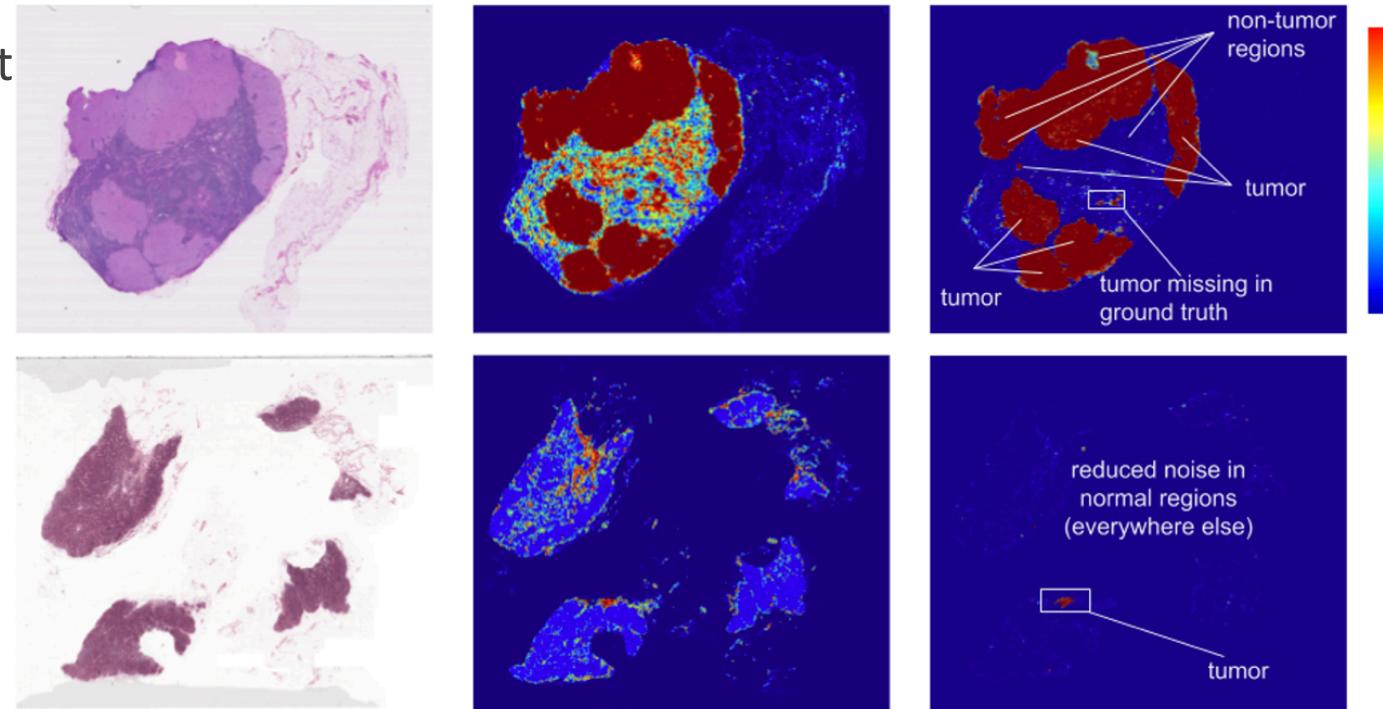


Medical Image Analysis with Deep Learning

- Researchers at IBM estimate that medical images currently account for at least 90 percent of all medical data, making it the largest data source in the healthcare industry.

- Inception v3 by Google is an example of AI-based image analysis that works with DNA and cancer data.

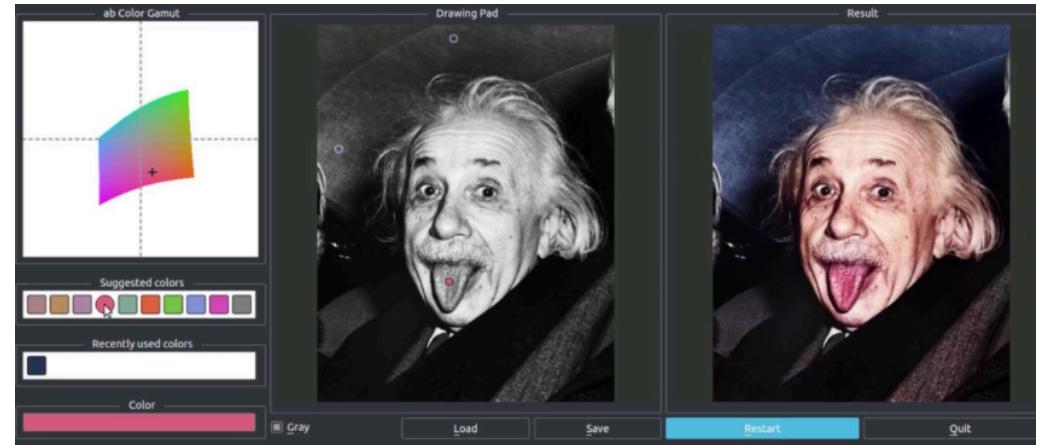
- Developers used thousands of images of both healthy and cancerous tissues. Inception v3 was able to advance on its own and learn the difference between the two types of tissues.
- Inception v3 can also find mutations inside the DNA of cancer cells, helping doctors discover mutations and get ahead of the disease with appropriate treatment



The picture shows that deep learning-based image analysis can detect lymph node tumor

AI-Powered App Helps You Colorize Black & White Photos in Seconds

- The researchers at UC Berkeley develop the automatic colorizer algorithm in 2016. It can colorize complex black and white photos accurately in seconds.

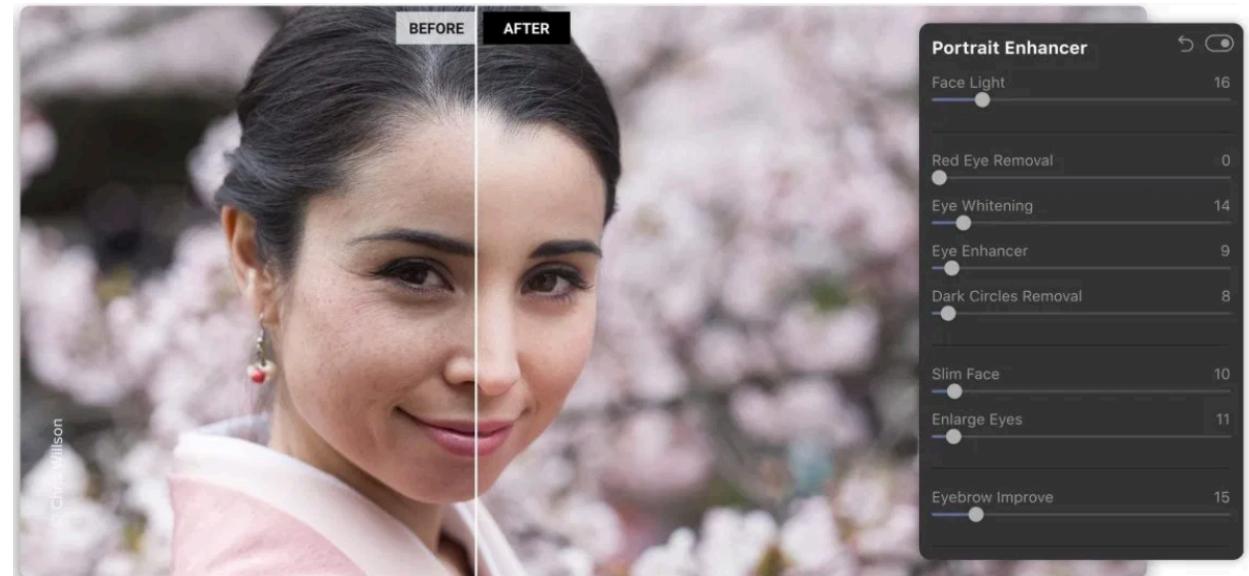


Business Applications:

- Image colorization attracts researchers in this field is Old Movies Colorizing.
- Image or video improvement for effective advertising campaign

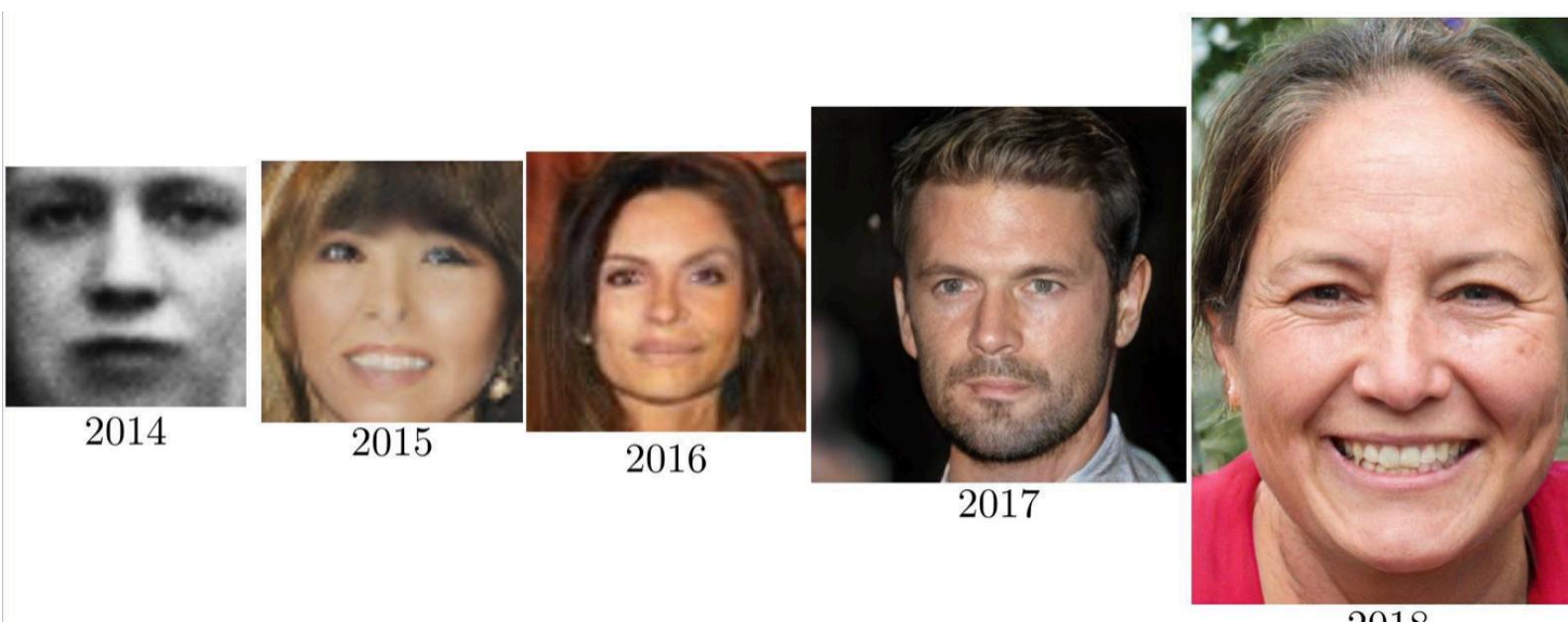
Luminar Uses AI to Sharpen Photos, Replace Skies, and Clean Faces

- AI photography tool Luminar is leveraging machine learning to automate the process of professional-class photo editing.
- The app uses machine learning for content-aware results, isolating and enhancing only the specific areas of photos that are “important.”
- The tool looks for people, clouds, water, and buildings, then intelligently tweaks their sharpness in ways that are appropriate to their context rather than jarringly different.



AI-generated Images

- Today, AI can create realistic images and videos of cats, products, faces that aren't of real people, your voices and even original works of art.



- Each of the faces in the image from the left was generated by an AI.
- Starting with the faces on the left, from 2014, you can see how dramatically AI capabilities have improved.

AI-generated Images

- In fact, there's even a market for AI's original artwork—Google hosted an art show to benefit charity and to showcase work created by its software DeepDream. It sold an AI-generated piece of art that was a collaboration between human and machine for \$8,000 plus others.

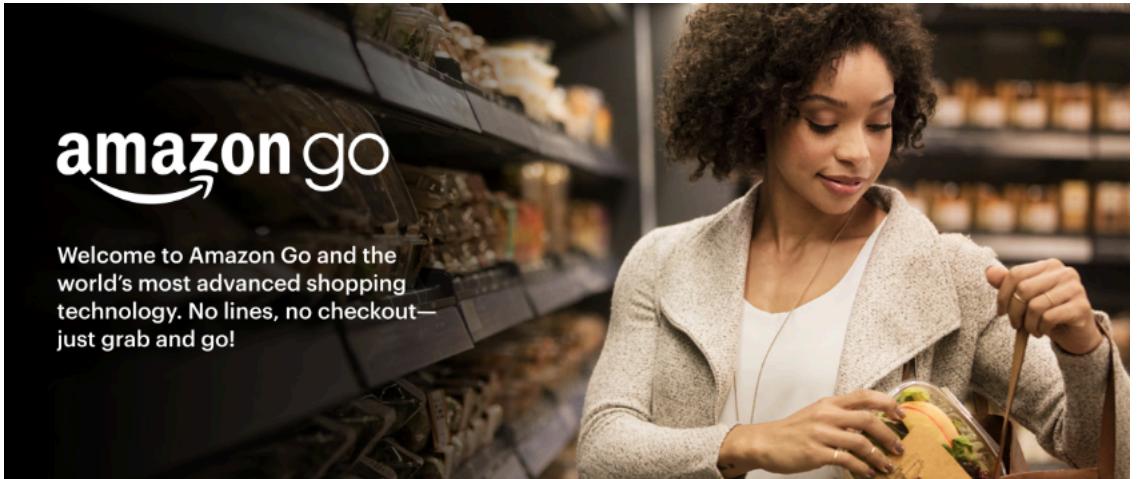


British auction house Christie sold its first piece of AI-generated art, "Portrait of Edmond Belamy," for \$432,500.



Amazon Go May Soon Change The Way We Shop

Amazon Go is an automated grocery stores that customers are able to purchase products without being checked out by a cashier or using a self-checkout station.



Go technology, a complicated array of cameras and software, figures out what shoppers have grabbed and automatically charges them when they exit.

Amazon Go – The Future

- Amazon is reportedly eyeing to open 3,000 Amazon Go stores by 2021 and is said to be looking at expanding the concept to London, airports and colleges.
- The Amazon Go team will soon expand and apply the Go technology to Wholefoods and other supermarkets.
- The company will open much larger locations equipped with its technology, which range from 1,500 to 3,000 square feet.



Deep Learning: Text Processing

Create a Personalized Poem, with The Help of AI

- The project, entitled 'Poem Portraits', lets you 'donate' a word of your choice to a poetry-writing algorithm, trained on over 20 million words of 19th century poetry. Those words are then "instantly incorporated into an original two-line poem" written on the fly by the algorithm.
 - <https://www.blog.google/outreach-initiatives/arts-culture/poemportraits/>

Our sky in the sun, stands still to the sea,
My rain and stars are washed into the woods.

POEMPORTRAITS by Es Devlin

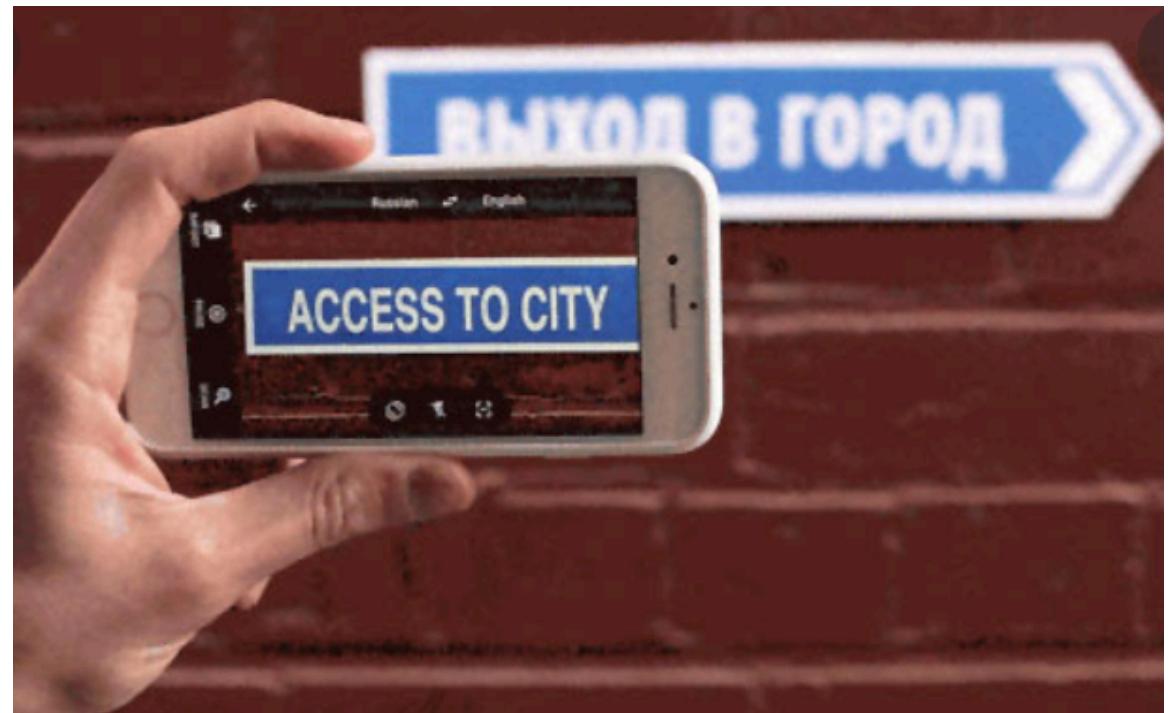
Google Arts & Culture

Translate What You See through Your Camera

- Google Translate mobile app has the instant camera translation, which allows you to see the world in your language by just pointing your camera lens at the foreign text.

How Google translate works?

- Google's AI translation methods is known as neural machine translation (NMT).
- These models have been incorporated into Google Lens and the web version of Translate, but they are now supporting instant camera translation.



Predict Stock Prices through Natural Language Processing

- Early in 1998, Wuthrich et al. attempted to predict stock markets based on online news articles such as The Wall Street Journal.
- Now, the natural language processing community correlates the text contents with the sentiment (positive or negative) of financial forums posts to predict the stock prices.



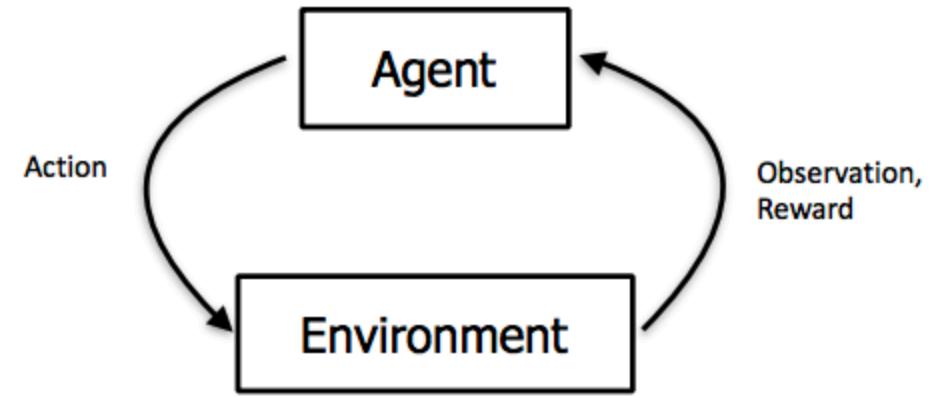
Another type of study is about applying social media text mining for stock market prediction.

- The method leverages market information contained in high-volume social media data rather than news articles.

Deep Learning: Reinforcement Learning

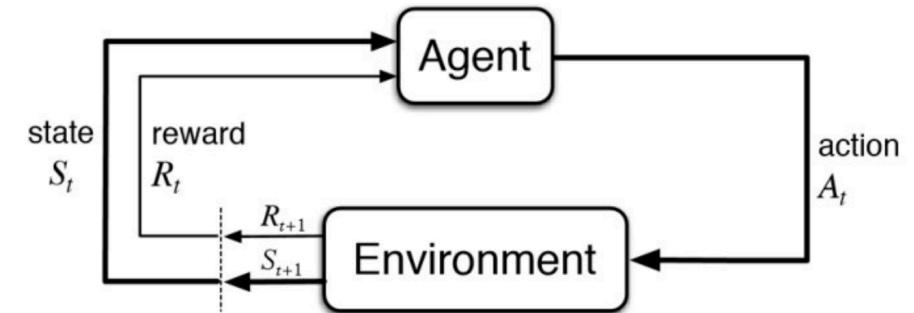
Reinforcement Learning

- Reinforcement Learning(RL) is a type of machine learning technique that enables an agent to learn in an interactive environment by trial and error using feedback from its own actions and experiences.
- The goal is to find a suitable action model that would ***maximize the total cumulative reward*** of the agent.



Reinforcement Learning

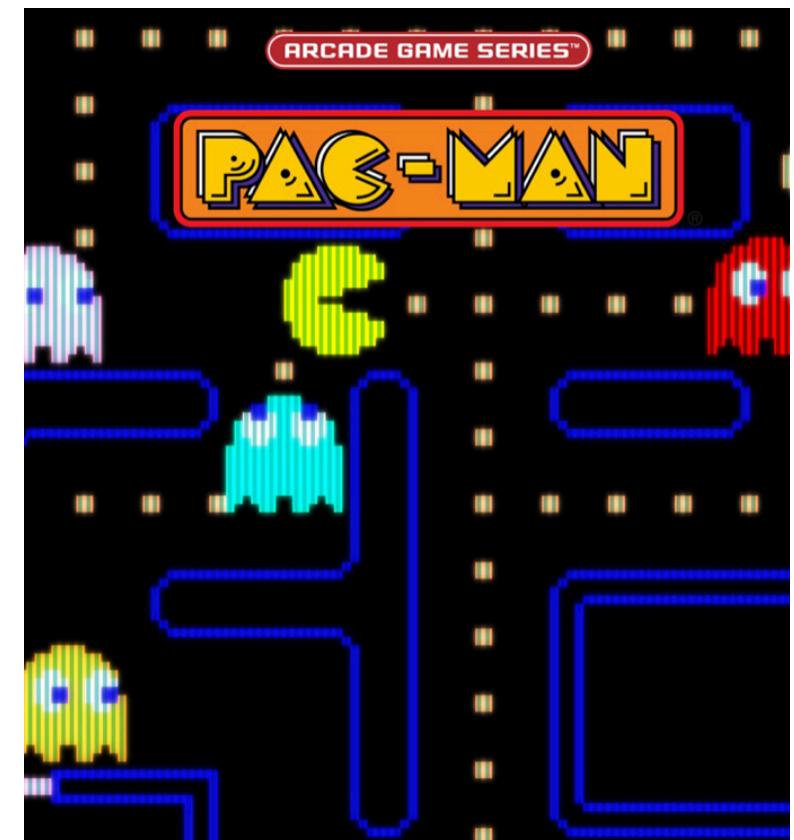
- Some key terms that describe the elements of a RL problem are:
 - **Environment:** Physical world in which the agent operates
 - **State:** Current situation of the agent
 - **Reward:** Feedback from the environment
 - **Policy:** Method to map agent's state to actions
 - **Value:** Future reward that an agent would receive by taking an action in a particular state



Explanation of Reinforcement Learning

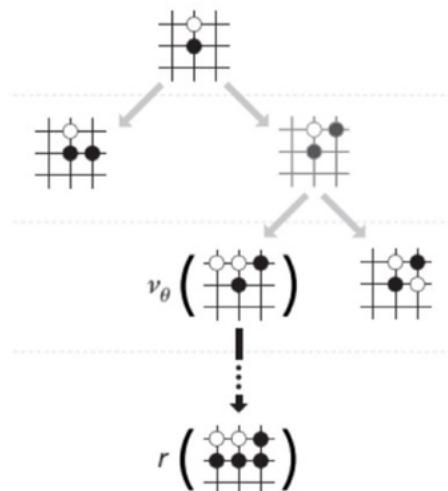
Reinforcement learning relies on the environment to send it a scalar number in response to each new action.

- Let's take the game of PacMan where the goal of the agent (PacMan) is to eat the food in the grid while avoiding the ghosts on its way.
- The grid world is the interactive environment for the agent. PacMan receives a ***reward for eating food*** and ***punishment if it gets killed*** by the ghost (loses the game). The states are the location of PacMan in the grid world and the ***total cumulative reward*** is PacMan winning the game.



Application - Reinforcement Learning

- Reinforcement Learning is quite widely used in building AI for playing computer games.
- **AlphaGo** and **AlphaGo Zero** are the first computer programs to defeat a world champion in the ancient Chinese game of Go.
- In the Go game, the algorithm searches the possible moves and finds the actions to win the game. Of course, the search space is too large and need to search smarter.



Application - Reinforcement Learning

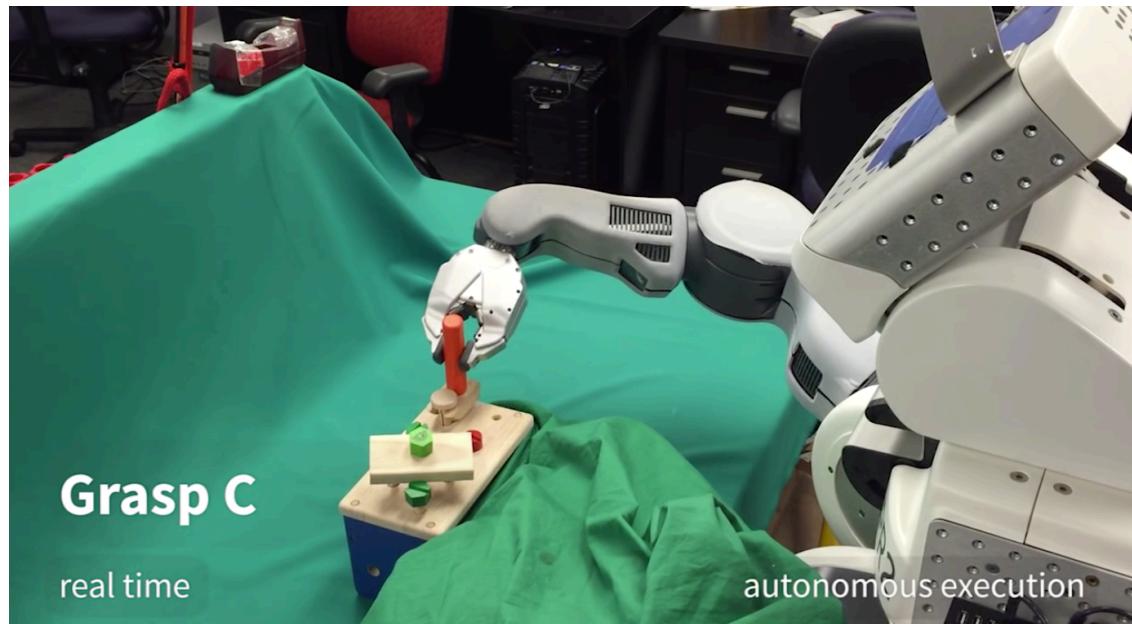
- AlphaStar: Mastering the Real-Time Strategy Game StarCraft II
- During the training, each agent experienced up to 200 years of real-time StarCraft play.



Application - Reinforcement Learning

■ Robotics:

- While designing robotic systems that effectively perform repetitive tasks in controlled environments, like building products on an assembly line, is fairly routine, designing robots that can observe their surroundings and decide the best course of action while reacting to unexpected outcomes is exceptionally difficult.
- Instead of programming the robot directly, the robot is trained to learn policies to map raw video images to robot's actions. Once it is done, the robot should handle situations that have not trained before.



Deep Learning: Knowledge Distillation

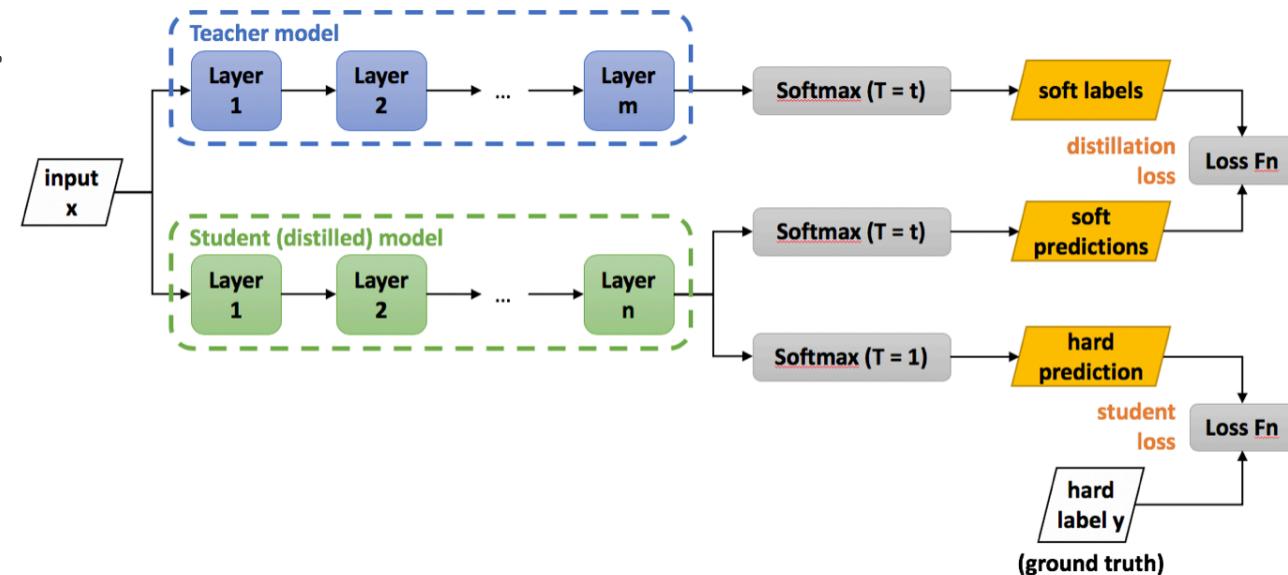
Knowledge Distillation

- Knowledge distillation is model compression method in which a small model is trained to mimic a pre-trained, larger model (or ensemble of models). This training setting is sometimes referred to as "teacher-student", where the large model is the teacher and the small model is the student.
 - The smaller (student) model is a pre-defined architecture which just has a smaller number of parameters compared to the teacher model.
 - This small network will be able to produce comparable results. It can even be made capable of replicating the results of the cumbersome network.



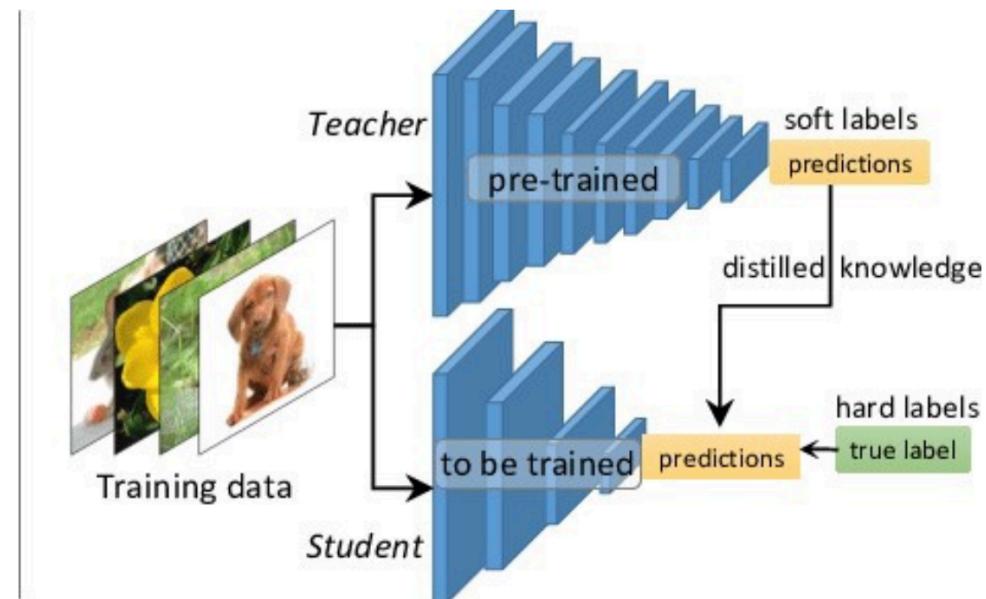
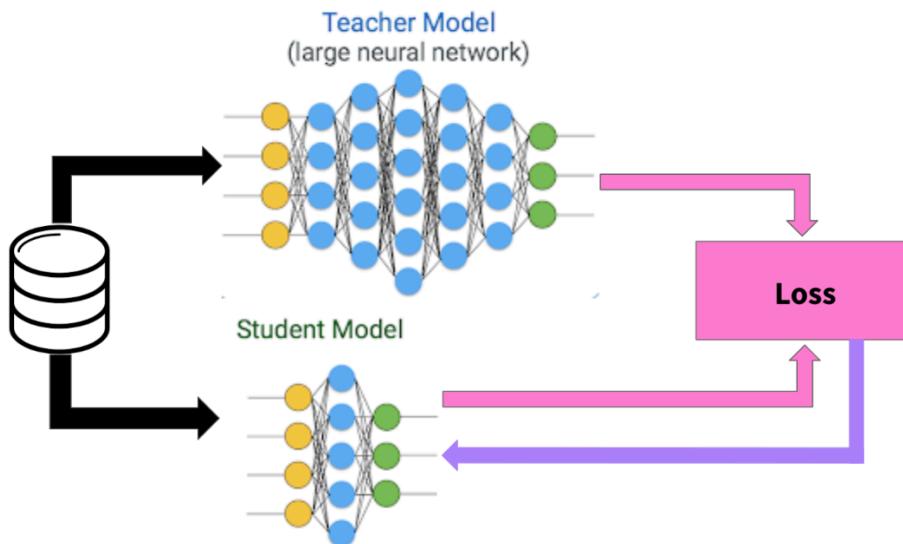
Process of Knowledge Distillation

- First, a large and complex network (teacher model) that can extract important features from the given data is trained and can therefore produce better predictions.
- Then, we train a small network (student model) with the help of the cumbersome model. Knowledge is transferred from the teacher model to the student by minimizing a loss function in which the target is the distribution of class probabilities predicted by the teacher model.



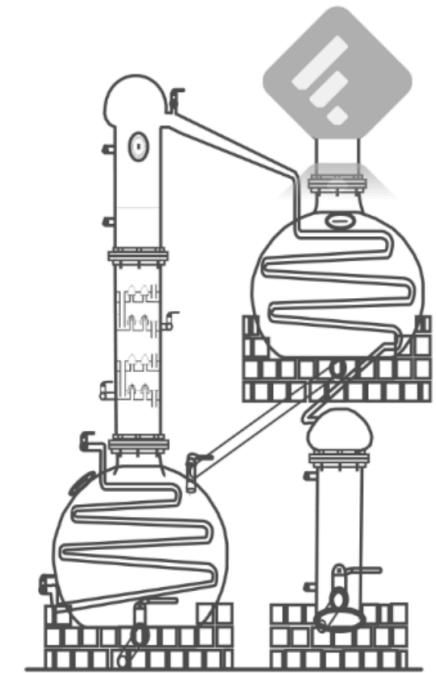
Knowledge Distillation

- Neural models have been successful in almost every field including extremely complex problem statements. However, these models are huge in size, with millions (and billions) of parameters, and thus cannot be deployed on edge devices.
- Knowledge distillation refers to the idea of model compression by teaching a smaller network, step by step, exactly what to do using a bigger already trained network.



Knowledge Distillation -- What's Next?

- There have been a lot of new modification suggested to the traditional student teacher described above, like introducing multiple teachers, introducing a teaching assistant, etc.
- However, the field is still pretty young and is quite unexplored in many dimensions.



Recommender Systems

Recommender Systems

- **What Are Recommender Systems?**
- Recommender systems are Machine Learning techniques that serve the best advice for a potential buyer.
- They suggest the most relevant items to buy and, as a result, increase a company's revenue. These suggestions are based on users' behavior and history that contain information on their past preferences.



Recommendation systems changed the way websites communicate with their users. Rather than providing a static experience in which users search for and potentially buy products, recommender systems increase interaction to provide a richer experience.

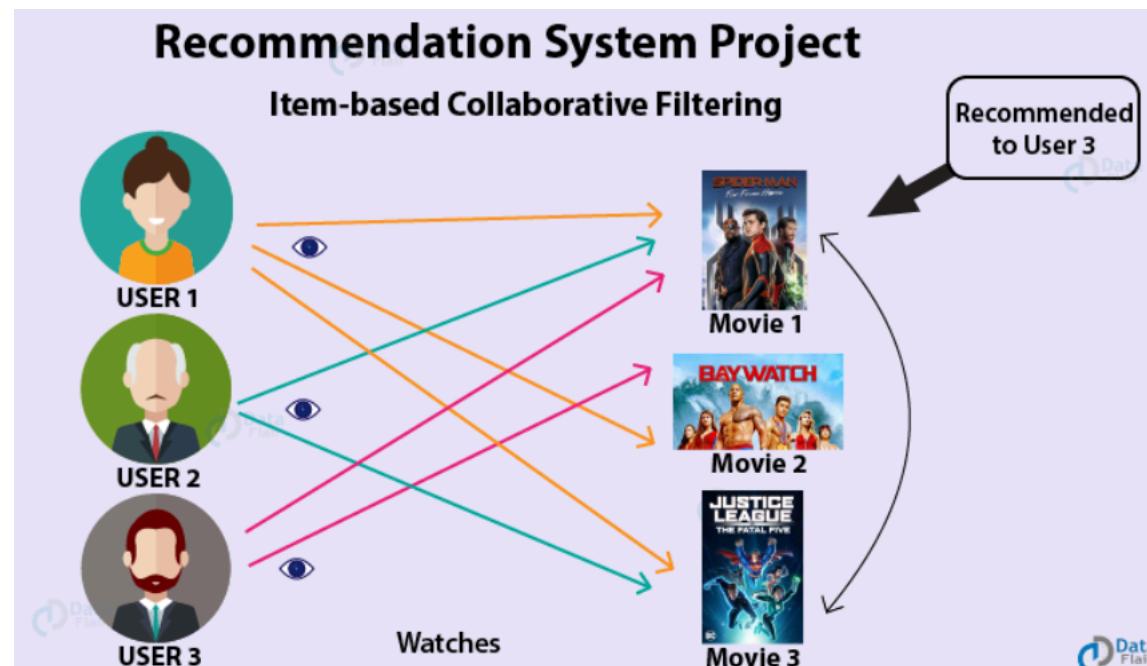
Types of Recommender Systems

The most common recommender system approaches are:

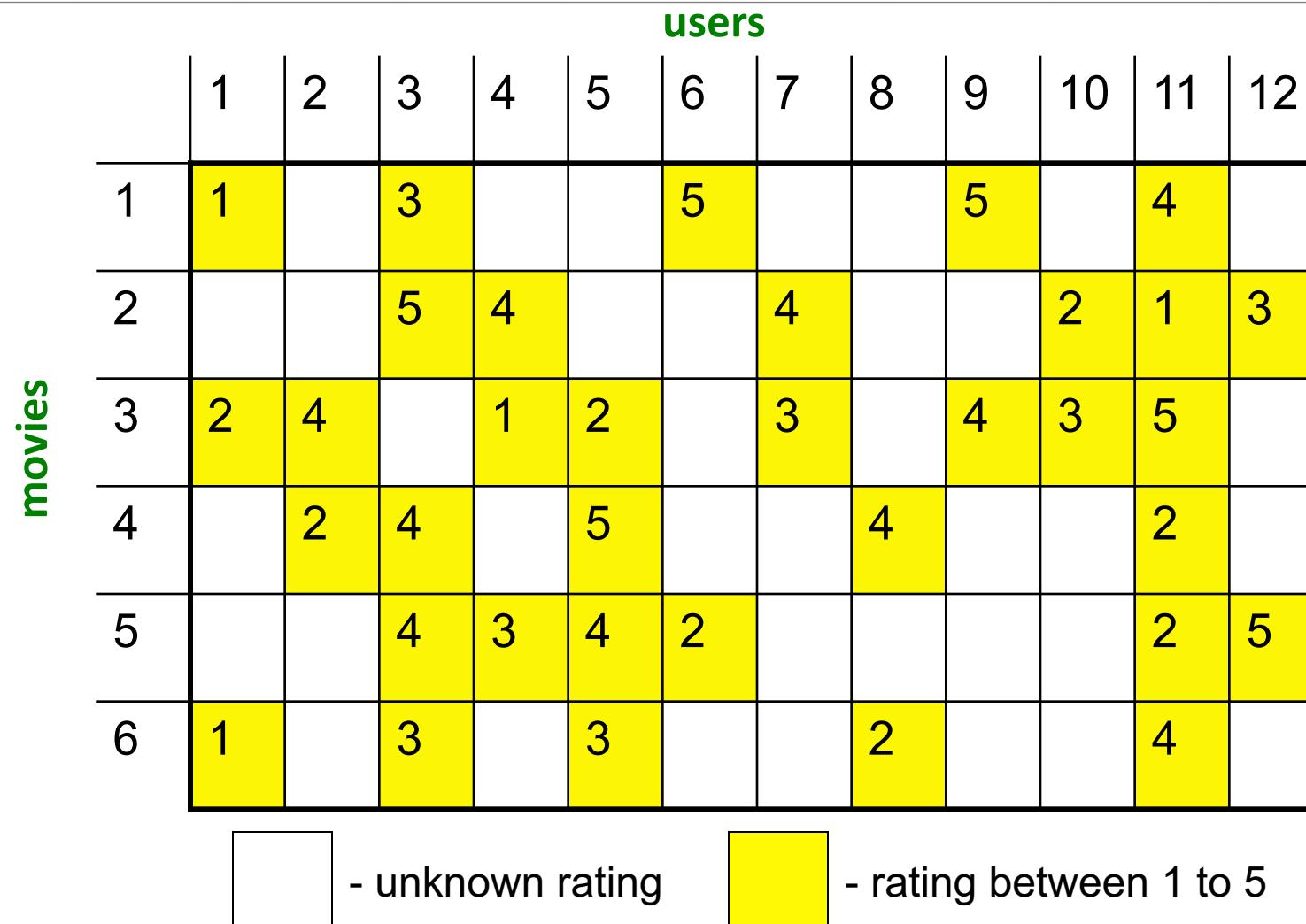
- **Collaborative filtering**
- **Content-based systems**
- **Knowledge-based systems**

Collaborative Filtering

■ **Collaborative filtering** processes and analyzes the history of users' preferences in the past, finds similarities in their choices, and classifies the users by their preferences. Then the system gives recommendations relying on the best matches. The idea is that users with common interests are more likely to choose the same items in the future.

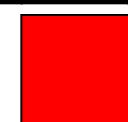


Collaborative Filtering



Collaborative Filtering

	1	2	3	4	5	6	7	8	9	10	11	12
1	1		3		?	5			5		4	
2			5	4			4			2	1	3
3	2	4		1	2		3		4	3	5	
4		2	4		5			4			2	
5			4	3	4	2					2	5
6	1		3		3			2			4	

 - estimate rating of movie 1 by user 5

Collaborative Filtering

Here we use Pearson

correlation as similarity:

1) Subtract mean rating m_i from each movie i

$$m_1 = (1+3+5+5+4)/5 = 3.6$$

row 1: [-2.6, 0, -0.6, 0, 0, 1.4, 0, 0, 1.4, 0, 0.4, 0]

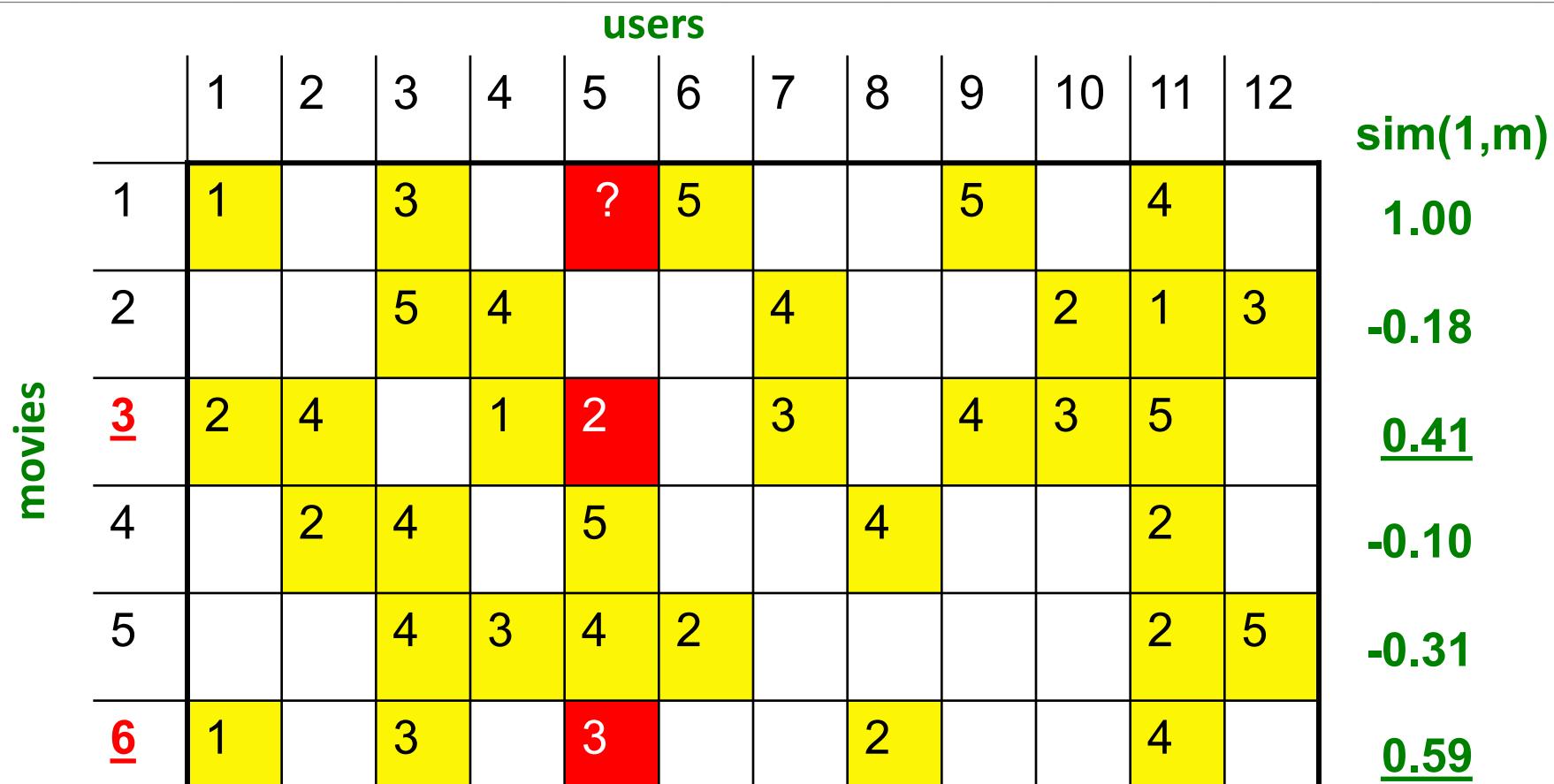
2) Compute cosine similarities between rows

	users												
	1	2	3	4	5	6	7	8	9	10	11	12	
movies	1	1		3		?	5			5		4	sim(1,m)
2				5	4			4			2	1	3
3	2	4		1	2			3		4	3	5	0.41
4		2	4		5			4			2		-0.10
5			4	3	4	2					2	5	-0.31
6	1		3		3			2			4		0.59

Neighbor selection:

Identify movies similar to
movie 1, rated by user 5

Collaborative Filtering



Compute similarity weights:

$$s_{1,3}=0.41, s_{1,6}=0.59$$

Collaborative Filtering

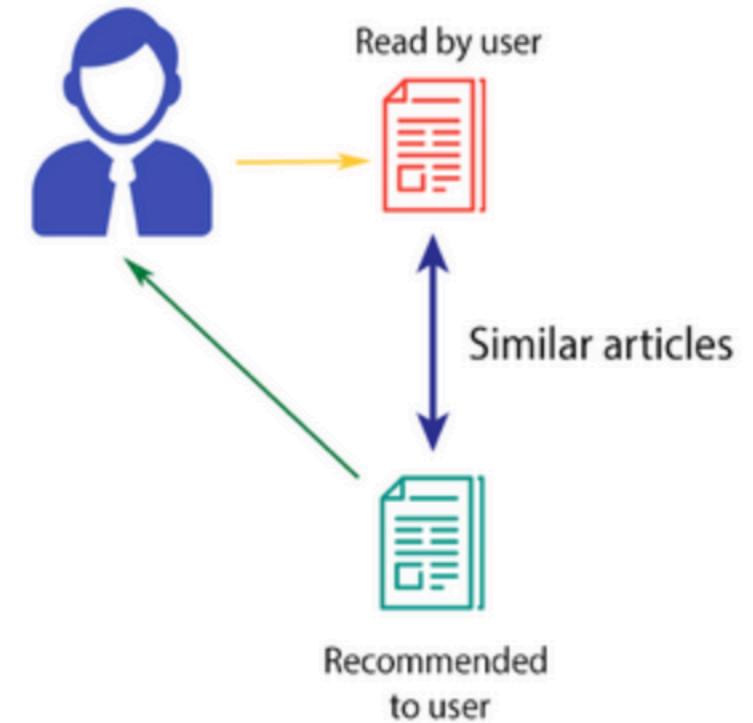
	users											
	1	2	3	4	5	6	7	8	9	10	11	12
1	1		3		2.6	5			5		4	
2			5	4			4			2	1	3
3	2	4		1	2		3		4	3	5	
4		2	4		5			4			2	
5			4	3	4	2					2	5
6	1		3		3			2			4	

$$r_{1.5} = (0.41*2 + 0.59*3) / (0.41+0.59) = 2.6$$

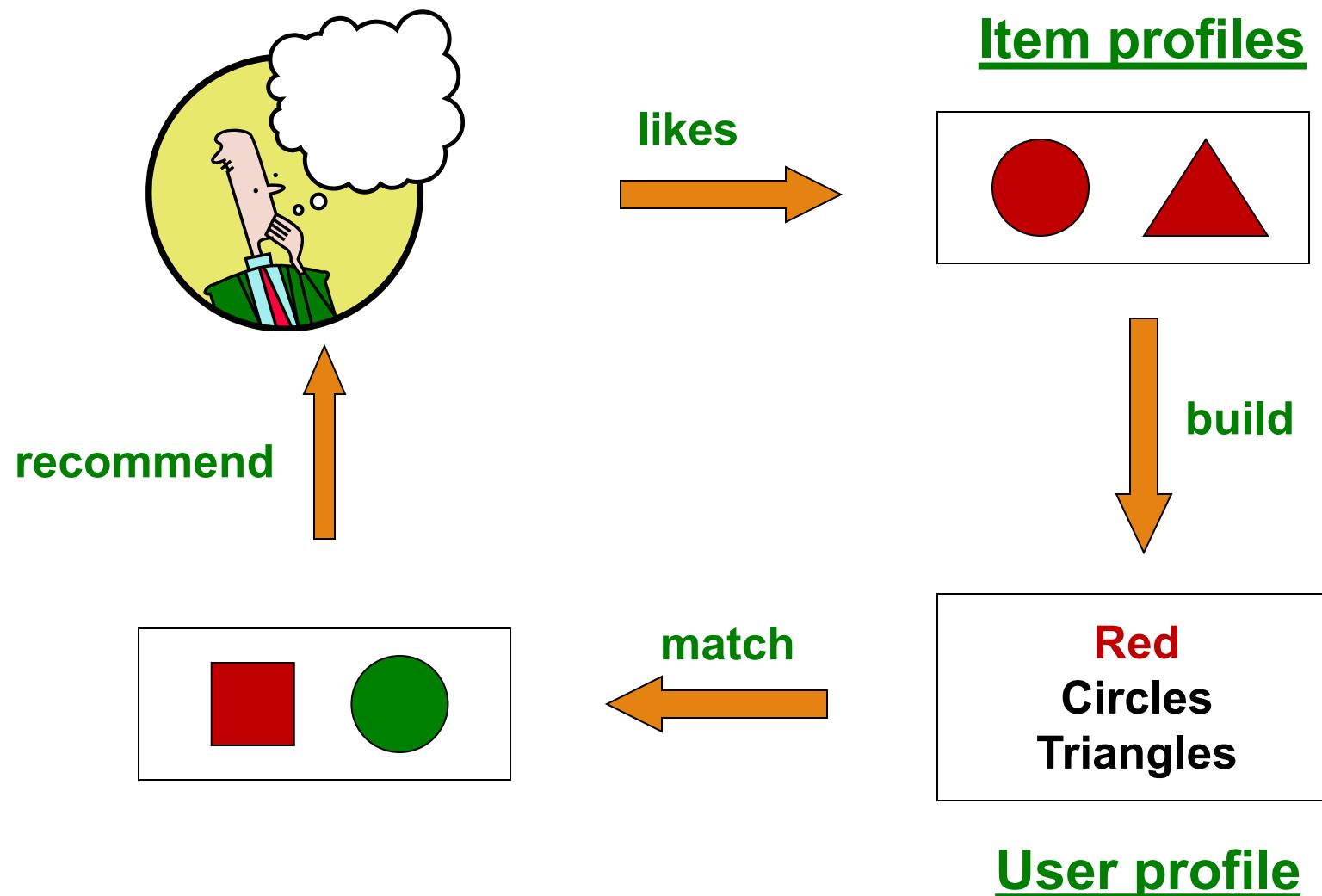
Content-Based Recommender Systems

- The content-based approach relies on the criteria of an item and doesn't require its users to interact or give any feedback.
- Each item has its own attributes and description. Using these attributes, the system will try to find the best match for the user according to their interests and offer the best item available.

CONTENT-BASED FILTERING

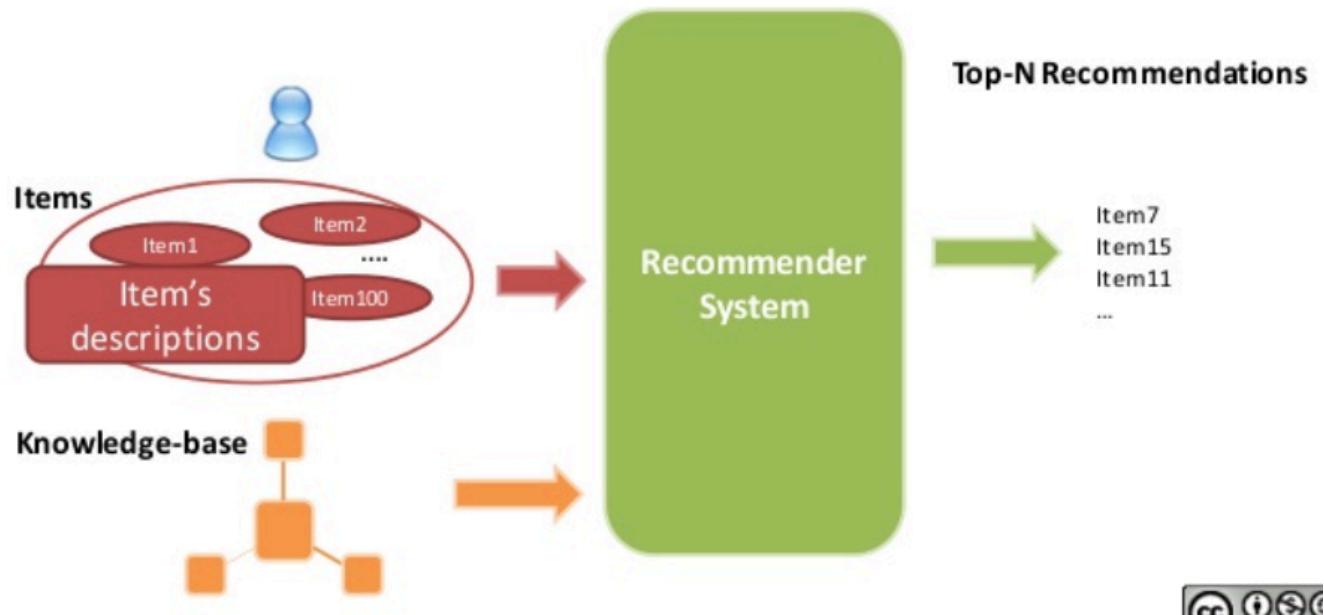


Content-based systems



Knowledge-based Recommender Systems

Knowledge-based recommender system consists of a range of products, user preferences, and recommendation guidelines. It is widely adopted in the following circumstances:



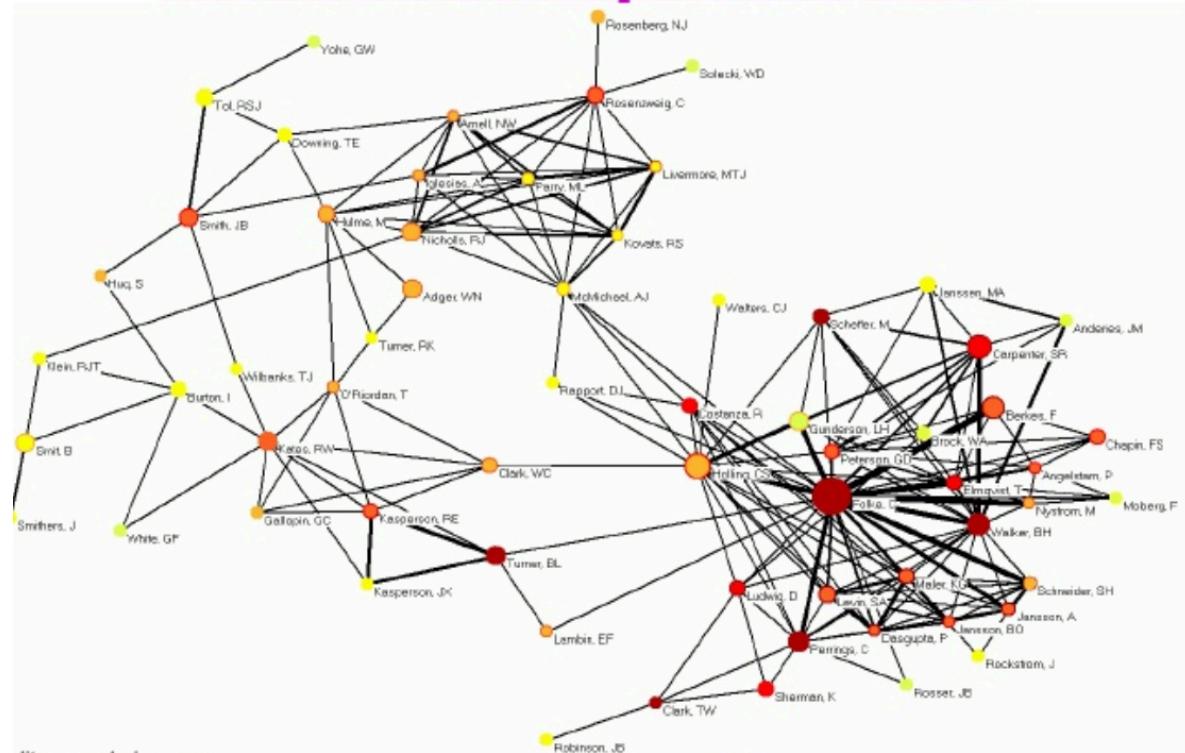
- When items are seldom purchased, such as real estate or cars
- When a user wants to choose specific features of an item, for example, travel tours or plane tickets for certain dates and locations
- When time and functionality are important, for example, for various electronic appliances where you need to choose from a model, year, technical features, and other parameters

Social Network Analysis

Social Network Analysis

- Social network analysis (SNA) is the process of investigating social structures through the use of networks and graph theory.
- Social network analysis has emerged as a key technique in modern sociology. It has also gained a significant following in biology, economics, information science, organizational studies, political science, and public health etc.

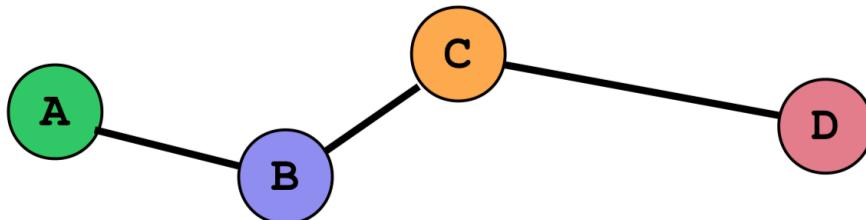
A Friendship Network



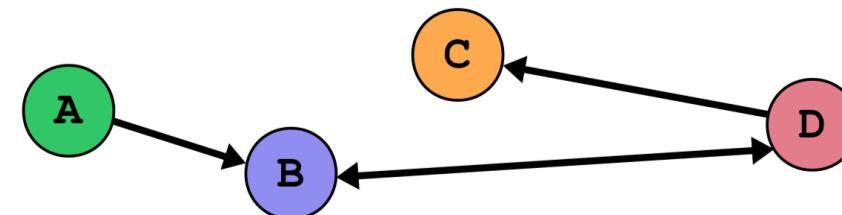
Definitions

- **Actor:** also called a **node** or a **vertex**, refers to an individual that can have relationships with other individuals.
- **Tie:** also called a **relation** or **edge**, describes a particular, well specified, relationship between two **Actors**. This could refer to a relationship like “went to the same school” or “likes potato chips” or something like “likes” or “trades with”. Ties can be **un-directed** and **directed**.

Undirected Ties



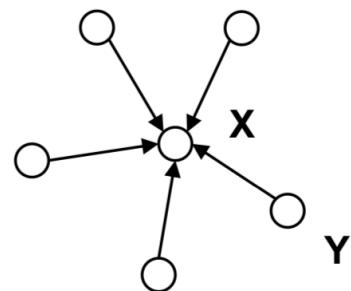
Directed Ties



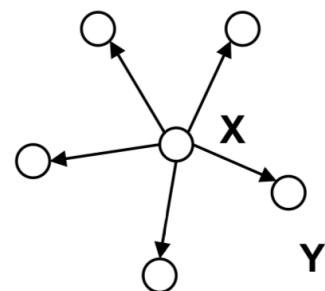
Centrality

Centrality: Who's Important Based On Their Network Position

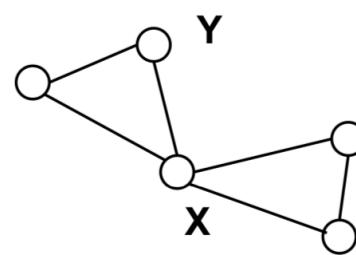
A central actor is one involved in many ties.



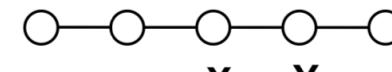
indegree



outdegree



betweenness



closeness

Centrality

- **Degree centrality:** number of immediate connections a node has (undirected). E.g., He or she who has many friends is most important
- **Prestige centrality:** everyone points to this actor (directed)
 - Number of in-links

Centrality

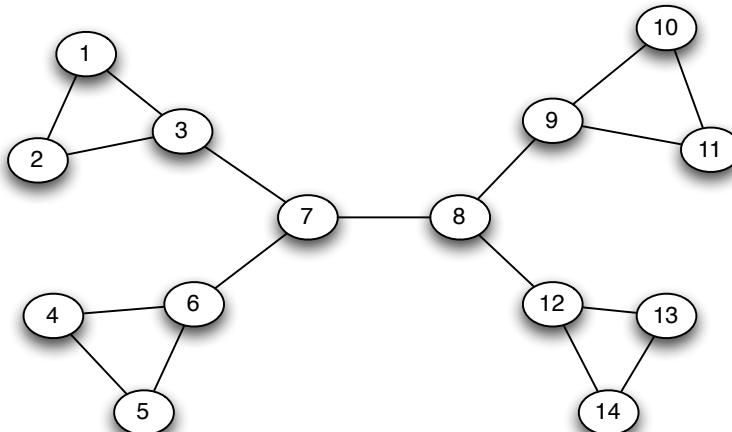
Betweenness Centrality

Intuition: how many pairs of individuals would have to go through you in order to reach one another in the minimum number of hops?

A node with high **betweenness**

- lots of paths have to pass through it
- influences network, choke-point for information
- failure is a problem

Betweenness of node 7 should be high



Centrality

- **Closeness Centrality**
- Closeness is based on the length of the average shortest path between a vertex and all vertices in the graph

Social Network Analysis - Influencer Marketing

How to find influencers through social network analysis?

- We can use centrality algorithms like degree centrality, betweenness centrality, and PageRank to find the most important people in online social network.
- Social media “influencers” are those with accounts that drive traffic and sales to a product or service based on their recommendations.
- Their ability to influence stems from an apparent personal relationship with their followers and a sense of authority in their respective marketing spaces.