



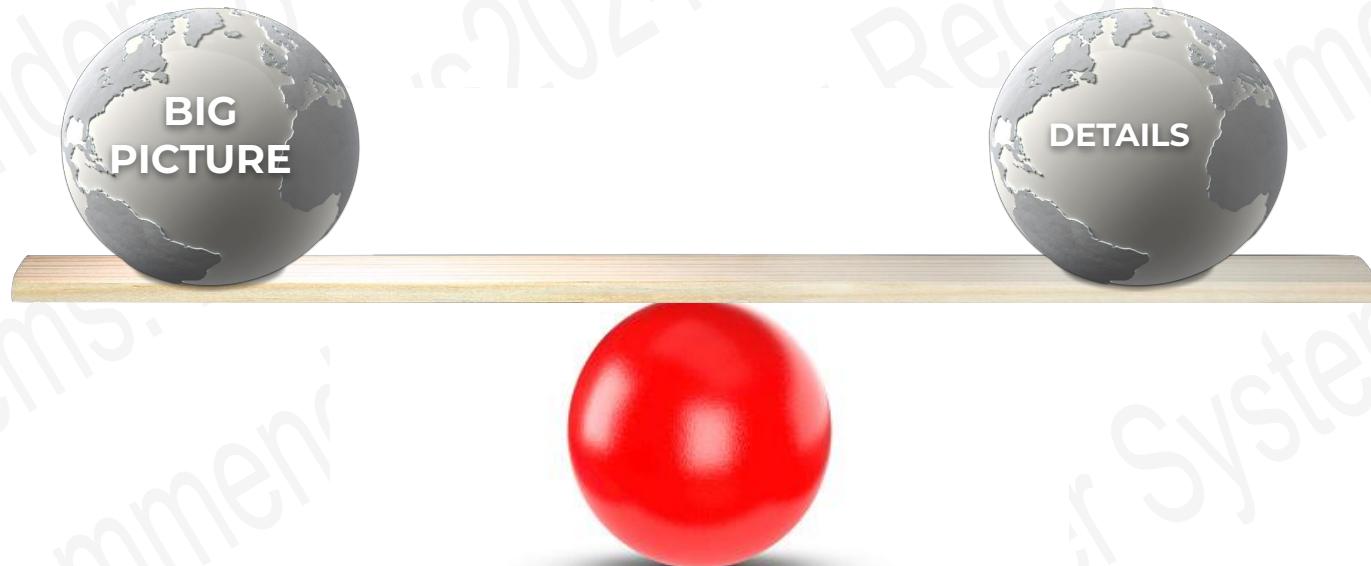
Introduction

Human-Centered Recommender Systems

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1. Background



Cyber-Physical-Social System (CPSS)

Cyber-Physical System (CPS)



Social

Cyber-Physical-Social System (CPSS)

"A system composed of **Physical component** monitored or controlled by a **Cyber component** (computer-based algorithm)."

US National Science Foundation

Examples: **Controlled devices**

- Sensors,
- Actuators,
- Robotics systems, etc.

Human was missing in the design process.

"A major **paradigm shift** to study the impact of **CPS** on **humans** and vice versa."

Fei et al. 2010

Examples: **Smart environments**

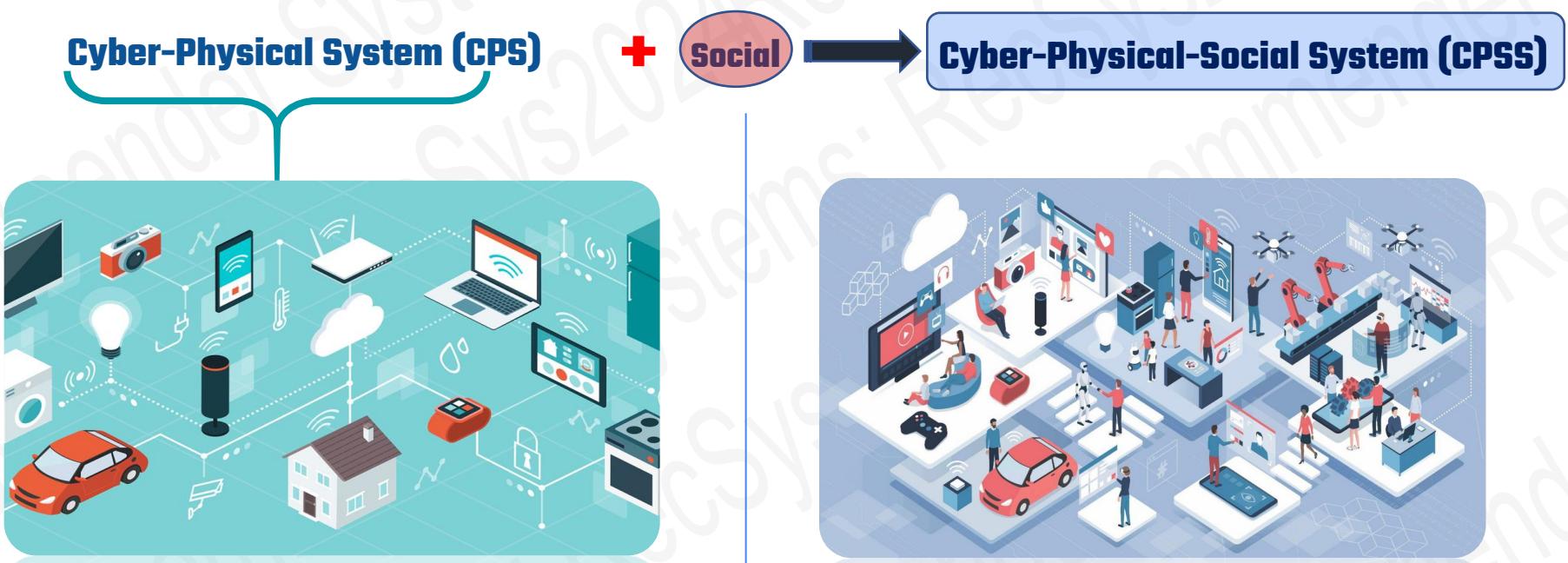
- Smart homes,
- Smart manufacturing systems
- Smart museums, etc.



Cassandras 2016

Enhance Human- CPS Interaction

Cyber-Physical-Social System (CPSS)

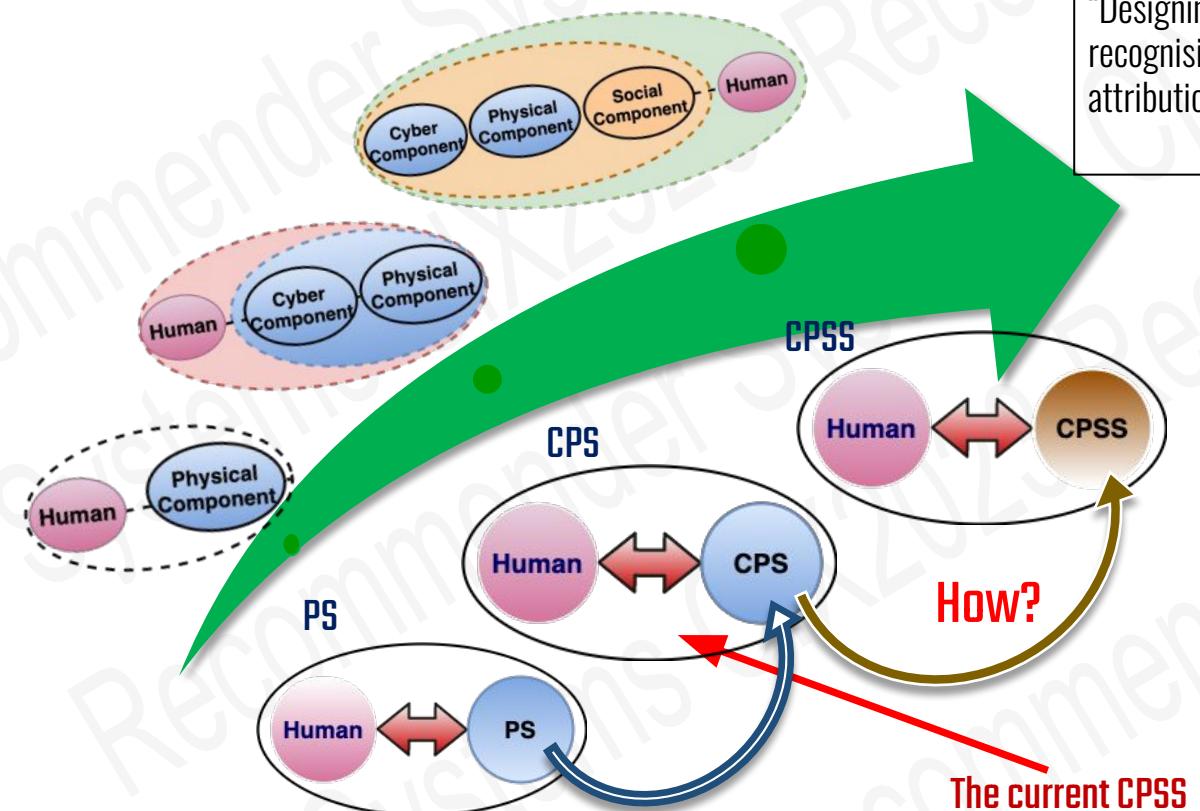


Concerned with the integration of

- **Computation,**
- **Networking** and
- **Physical processes**

Enhance Human- CPS Interaction

Cyber-Physical-Social System (CPSS)



"Designing a human-centric machine effectively requires recognising **human-like traits**, at least a metaphorical attribution of human-like qualities to non-human entities."

Duffy et al. 2003. (social Robotics)



Social component:- deeply ingrained in

- ✓ Emotional
- ✓ Cognitive and
- ✓ Behavioural facets.

Cyber-Physical-Social System (CPSS)

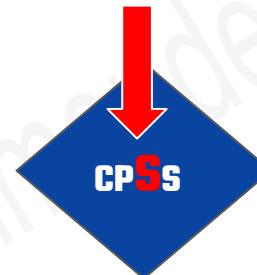
Personality in Social interaction:



“**Personality** describes the **unique patterns of thoughts, feelings, and behaviors** that distinguish a person from others. A product of both biology and environment, it remains fairly consistent throughout life.”

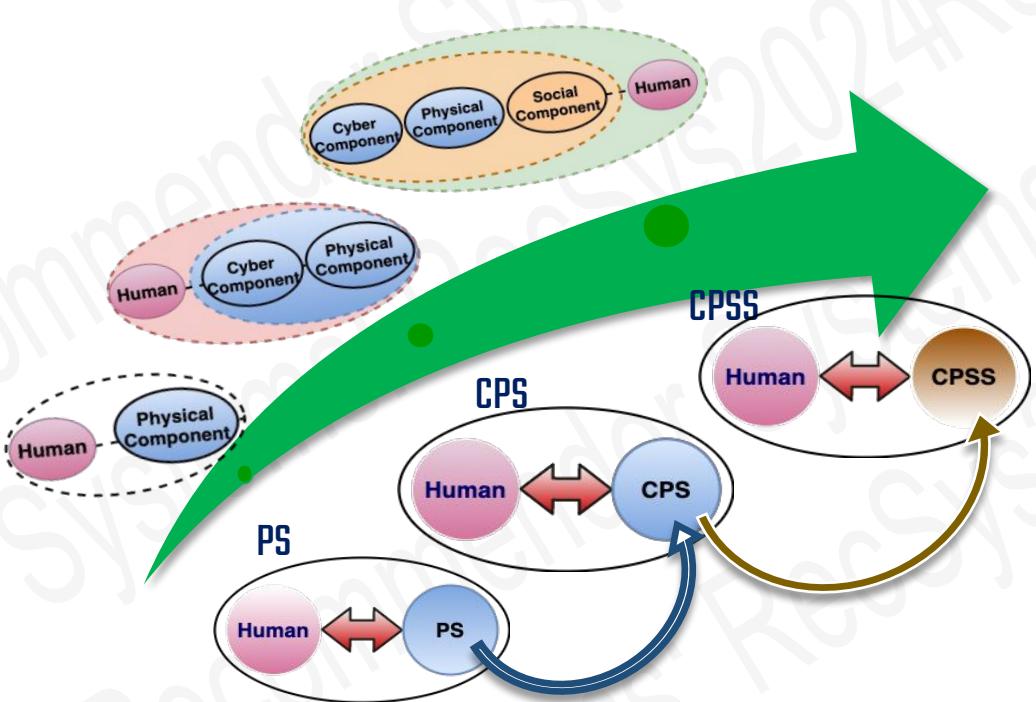
- Quality of experience: How well the individuals know each other?
- Recognising personal **preferences, interests** as well as **limitations** and **opportunities** such as **disability, knowledge** and **skills** of individuals becomes a necessity to ensure a seamless experience within a CPSS.

Personalization



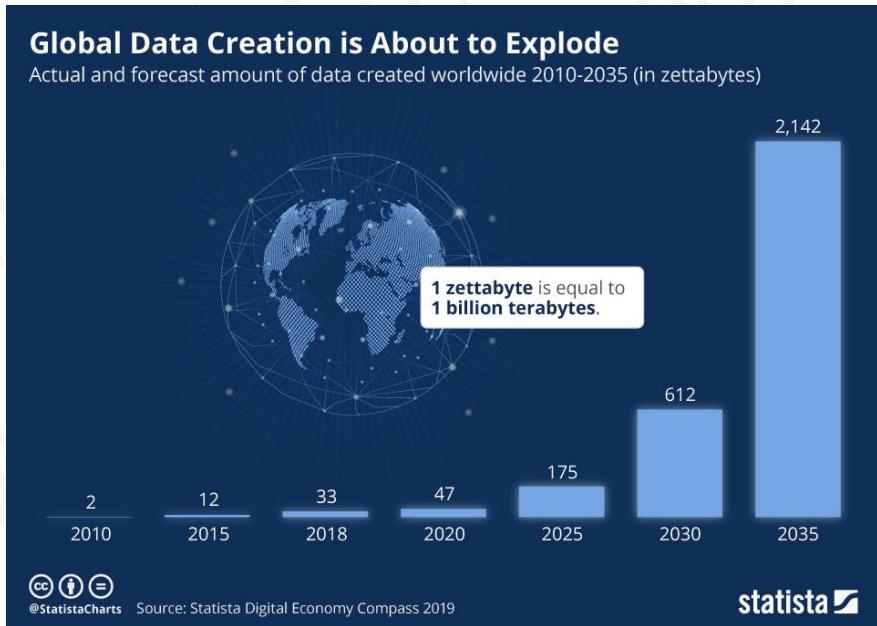
Since 1990's

Cyber-Physical-Social System (CPSS)

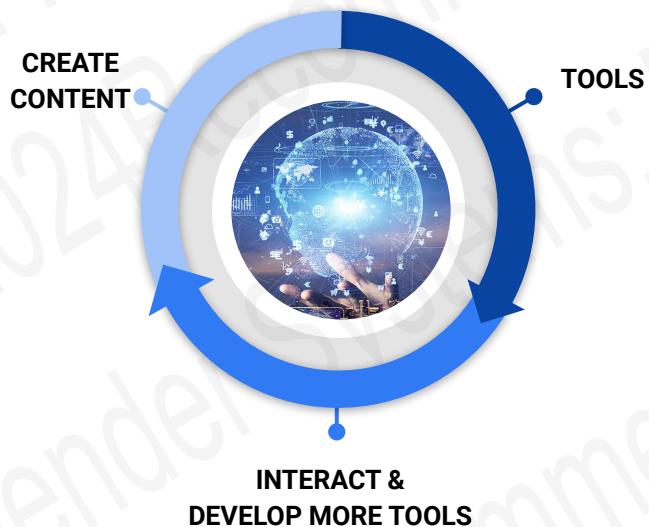


What came out of this evolution?

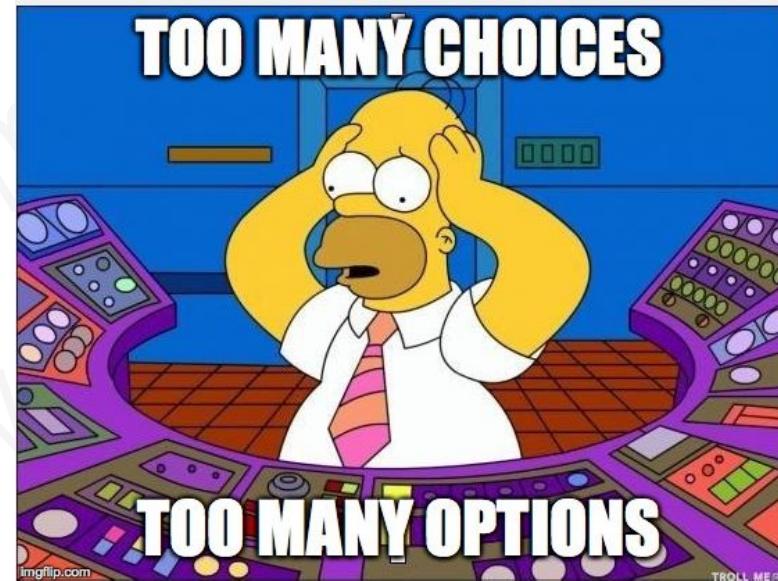
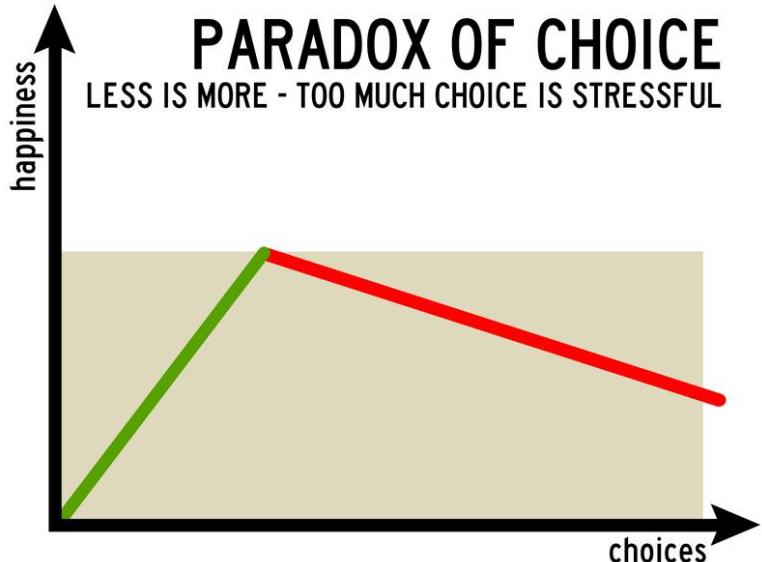




Limitless options on the web



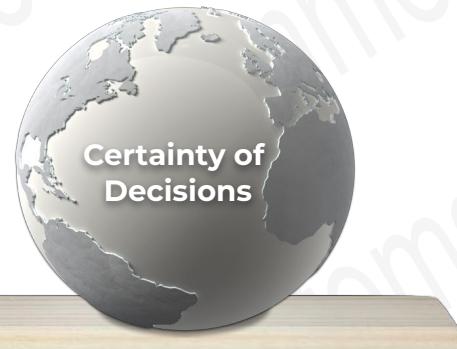
Abundance creates a problem





Source: Politiken (Based on Our Yale List)

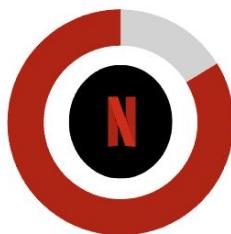
Decision making has become extremely challenging with the overwhelming number of products and services.



Recommender Systems (RecSys)



- “Algorithms that provide suggestions for items that are **presumed** most **pertinent** to a **particular user**.” [1]
- Typically, the suggestions refer to various **decision-making processes** such as:



80%
of content consumed on
Netflix is due to
recommendations.



60%
of video clicks on
YouTube's homepage
are attributed to
recommendations



35%
of its revenue is generated
by its recommendation
engine

- What **product** to purchase,
- What **music** to listen to,
- Which **movies** to watch,
- What **news** to read,
- Which **route** to take,
- Which **place** to visit, etc.

Recommender Systems (RecSys)

Personalization



Recommender Systems (RecSys)



Data

Machine Learning Model

Predictions

User Preference

Recommender System

Recommendations

Explicit Feedback



Implicit Feedback

Indirect behaviour towards an item.

- previous purchase
- previous watch
- previous read
- previous click
- etc.



Predict future behaviours



RecSys Paradigms



RecSys Paradigms

There are three common approaches to design Recommender Systems.

1. Collaborative Filtering,
2. Content-Based filtering and
3. Hybrid RecSys



1. Collaborative Filtering

"Similar users like similar things"



Users

- Subscribers
- Readers
- Buyers
- etc.

5	?	1	?	4		
?	?	?	?	?		
2	?	?	3	?		
4	?	2	?	1		

User-item interaction matrix

- Ratings
- Time spent
- Product clicked

New item

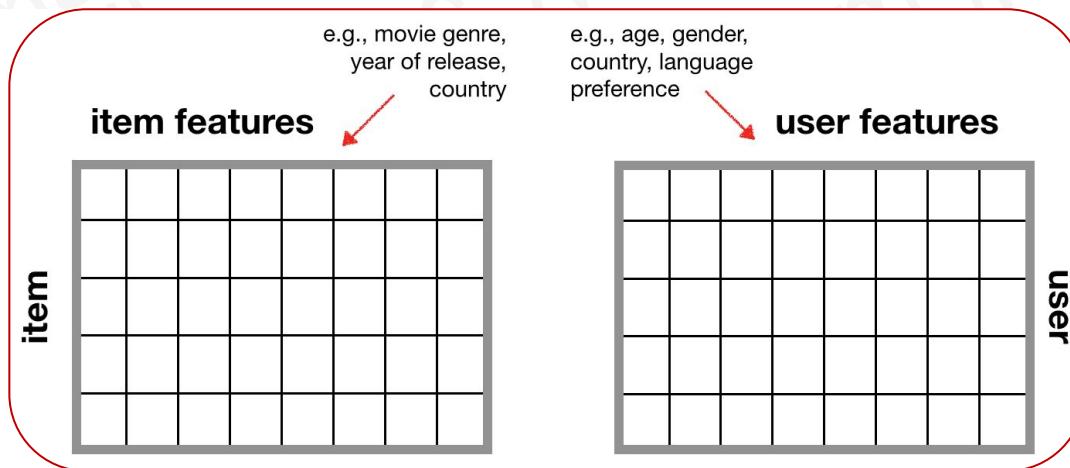
"Customers who bought this item also bought ... "

New user

Data

2. Content-Based Filtering

- Works based on the comparison of the analogy between the **user's profile** and **content** of the items.
- Use additional information about users and/or items ("Features") that explain the observed user-item interactions.



- Suffer less from **cold start** problem.
- Only new users/items with unseen features suffer from cold start problem.

3. Hybrid Recommender Systems:

- Combine **Collaborative Filtering (CF)** and **Content-Based Filtering (CBF)** approaches
- Usually take two forms
 - Train two models independently (one CF model and one CBF model) and combine their suggestions.
 - Directly build a single model that unifies both approaches (often a Neural Network)
 - Input (Prior information **user/item**) + **user-item** interaction



Modern RecSys Paradigms



Recent Approaches

- Multi-stakeholder aware RecSys
- Large Language Models (LLMs) as RecSys
 - Zero & Few shot RecSys

More in Session 3



The typical RecSys Pipeline

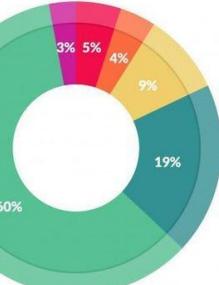
Data Pre-processing



Model Training

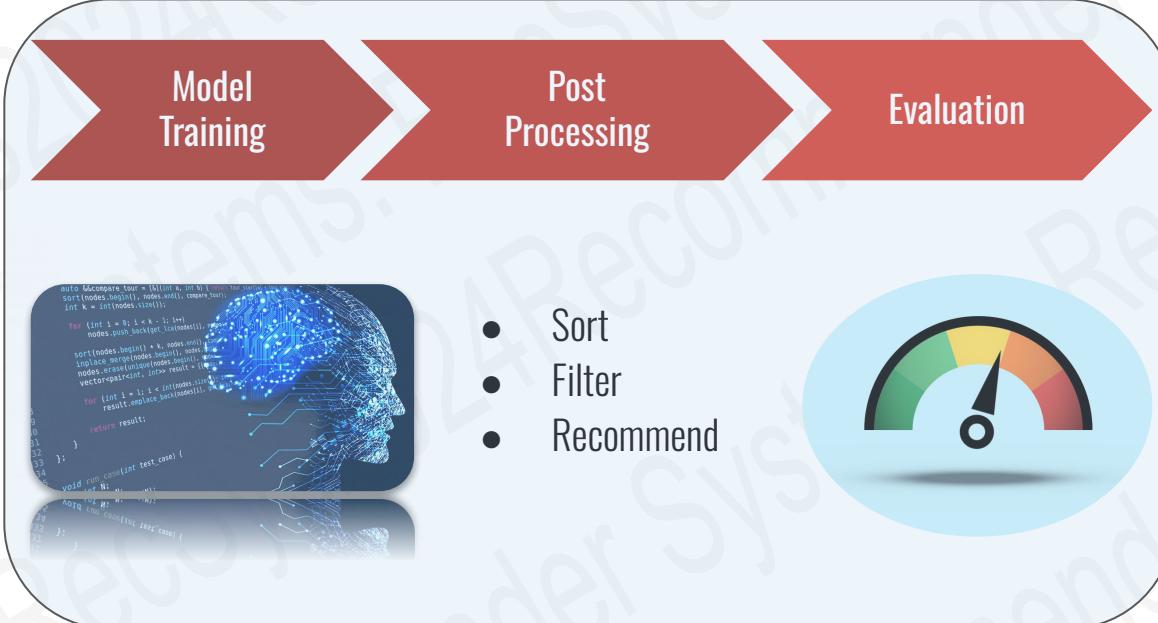
Post Processing

Evaluation



What data scientists spend the most time doing

- Building training sets: 3%
- Cleaning and organizing data: 60%
- Collecting data sets: 19%
- Mining data for patterns: 9%
- Refining algorithms: 4%
- Other: 5%



How good is the RecSys?

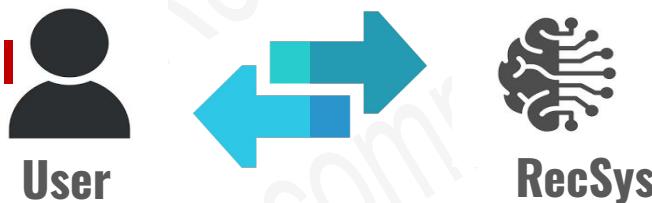
How good is the Evaluation metric?

“Describes an approach to recommender systems research and practice that focuses on understanding the characteristics of recommender systems, the characteristics of recommender systems users, and the relationships between them.”

Konstan and Terveen 2021

- The goal of **HC RecSys** is to design the **algorithms** and **interactions** of RecSys to better fulfill the goals of **users** and of **the organizations engaging with these users**.

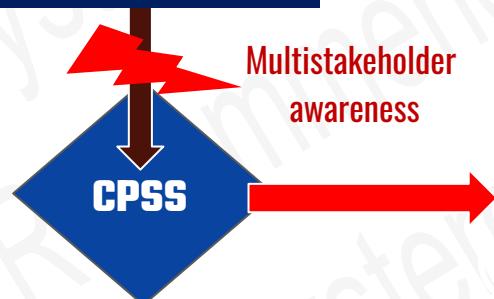
Where do we find a typical
Recsys User?



- ✓ People evolve in a **physical space** together with other people and smart devices.
- ✓ People do not always follow rules if they are not aligned to their preferences.

More in Session 3

Personalization





Human-Centered Recommender Systems (HC RecSys)



Human-centricity and the **metrics** used to evaluate a recommender system



Next → Session 2



→ **The HC RecSys pipeline: A case-study approach**