



Multi-Stakeholder aware Recommender Systems





Session 3



- A Multi-Stakeholder aware RecSys
- Formulating the RecSys Problem?
 - ◆ → (A framework)



Formulating a RecSys Problem



Task: Design a Personalised **Visual Art Recommendation** engine for NG/ Louvre

Formulating a RecSys Problem



Data
Pre-processing



Model
Training

Post
Processing

Evaluation



- Sort
- Filter
- Recommend



Understanding the context of the problem!

Formulating a RecSys Problem



Why does understanding the context matter?



Task: Design a Personalised **Visual Art Recommendation** engine for NG/ Louvre

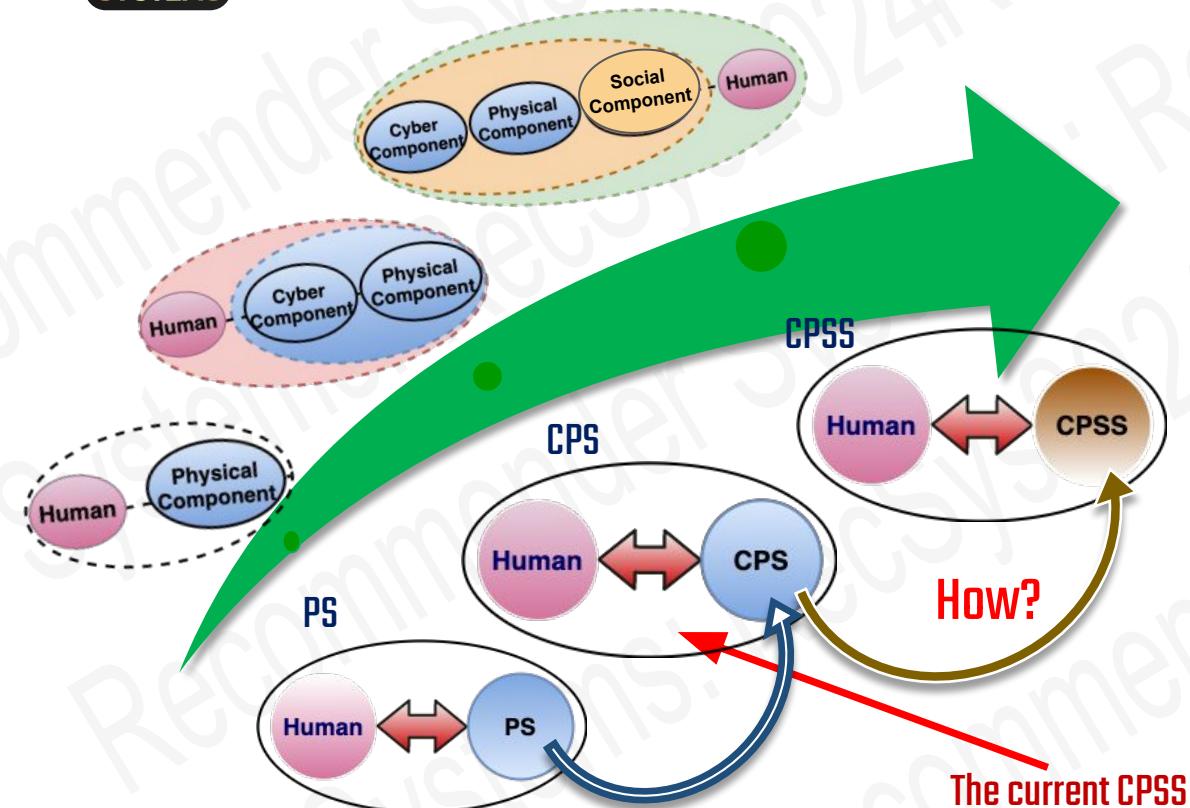
Museums as Cyber-Physical-Social Systems

- Points of Interest
- Smart devices (CPSS)
- Sensors, cameras, (CPS)
- Visitors



Personalization Task: Design a Personalized Visual Art Recommendation/ Guidance engines

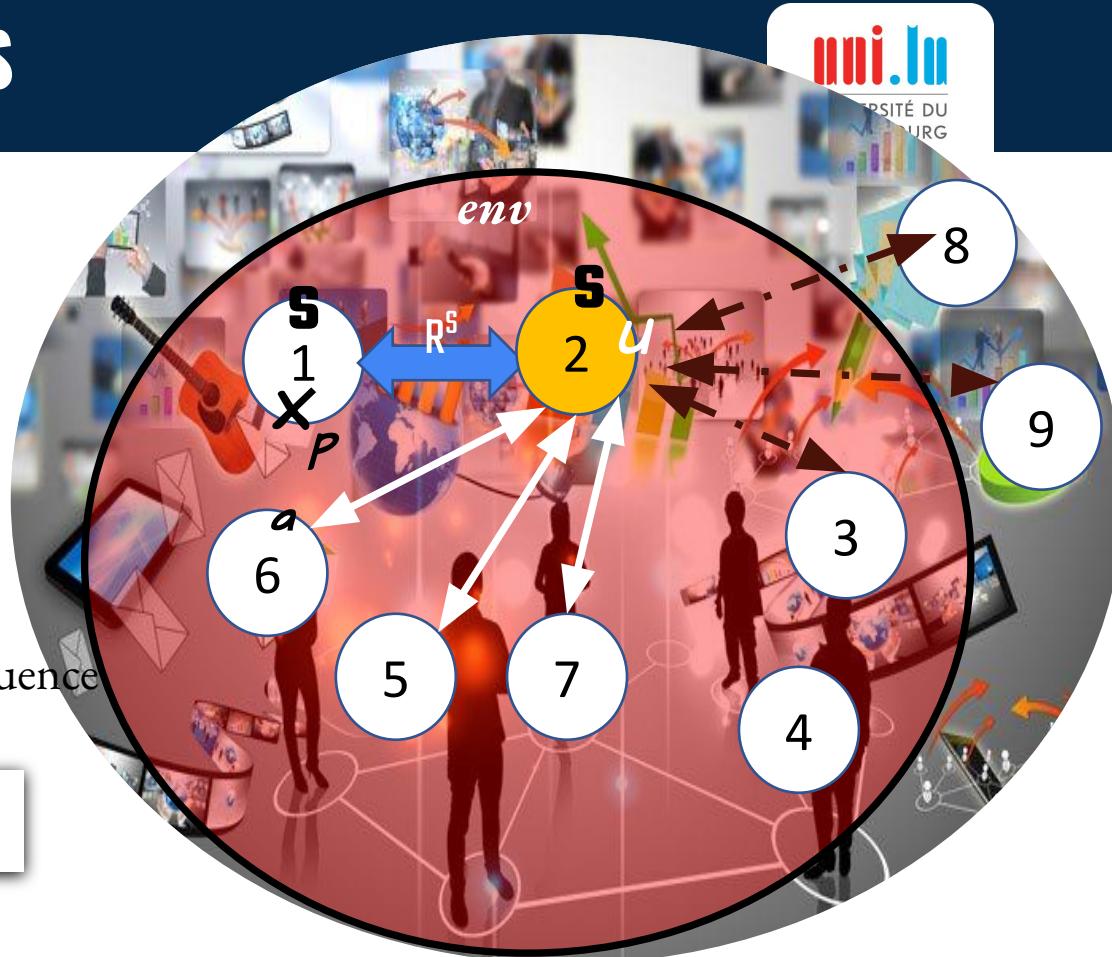
Cyber-Physical-Social System (CPSS)



Personalization in CPSS

- Smart system environment env ,
- **Personalisation** is a function of a social component S of a system.
- **Personaliser**(X_{pa});
- **User**(U)
- **Crowd**(Cr): direct influence
- **Context elements**(Cx): indirect influence

$$Pa^{cpss} = f(u, X_{pa}, cr, cx, env)$$



Formulating a RecSys Problem

Personalisation in exhibition areas for a user u can be formalised as a function of

- The user u ,  Visitor vs
- The personaliser X_{pa} ,  Mobile guide mg
- The crowd Cr ,  Crowd of other Visitors cr^{vis}
- The context elements cx
- The Smart environment env  Exhibition area ex

$$pa = f(u, X_{pa}, cr, cx, env) \quad \longrightarrow \quad pa^{Exhib} = g(vs, mg, cr^{vis}, ex)$$

Formulating a RecSys Problem

$$pa^{Exhib} = g(\mathbf{vs}, \mathbf{mg}, \mathbf{cr}^{vis}, \mathbf{ex})$$

➤ User (Visitor):

- Preferences/interests
- Time (Limited availability)
- Crowd tolerance
- Visiting style
- Fatigue
- (Disability)
- (Age)



Formulating a RecSys Problem



- **The Ant visitors:** spend a long time observing all exhibits moves close to the walls and the exhibits avoiding empty space.



- **The Fish visitors:** walk mostly through empty space making just a few stops and sees most of the exhibits but for a short time.



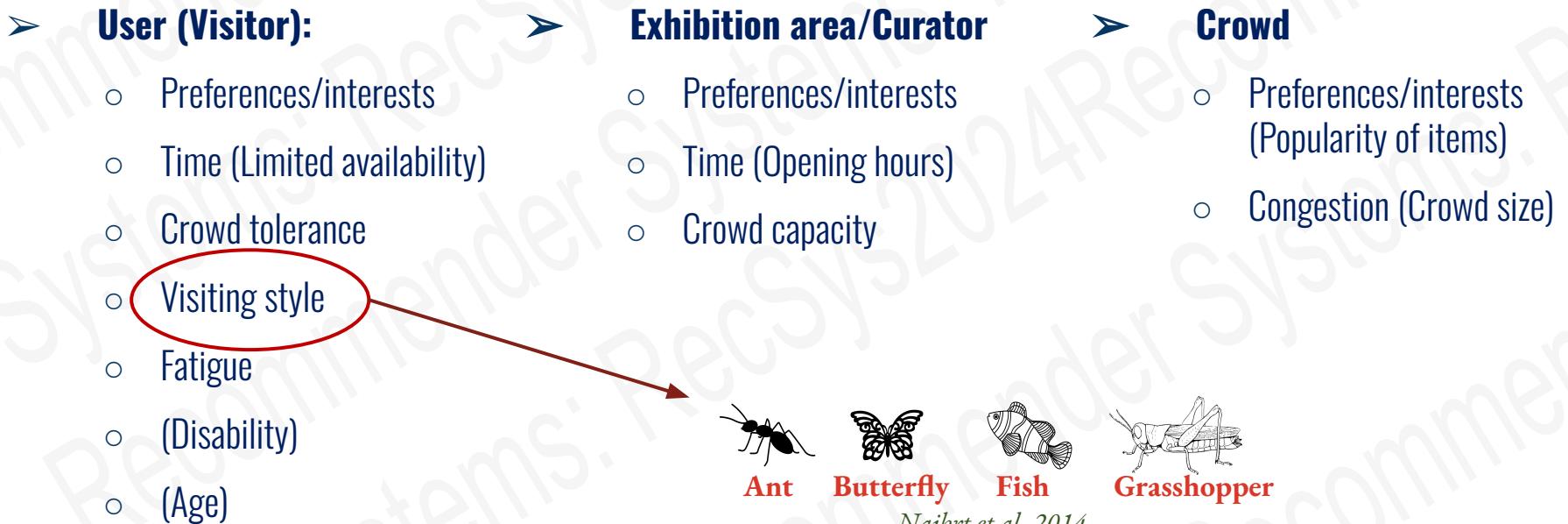
- **The Grasshopper visitors:** see only exhibits they are interested in and walk through empty space and stay for a long time only in front of selected exhibits.



- **The Butterfly visitors:** frequently change the direction of the tour route, usually avoiding empty space. They sees almost all exhibits, but times vary between exhibits.

Formulating a RecSys Problem

$$pa^{Exhib} = g(\mathbf{vs}, \mathbf{mg}, \mathbf{cr}^{vis}, \mathbf{ex})$$



Multi-Stakeholder aware RecSys

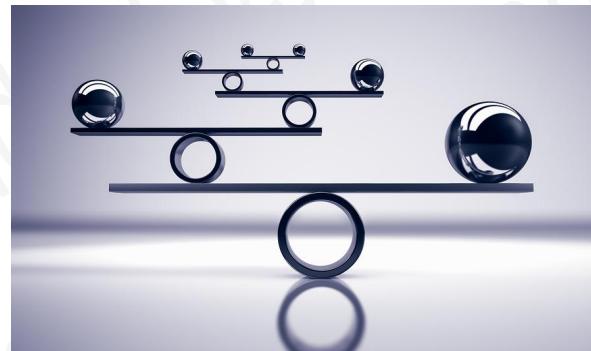


Curator-visitor tradeoff



$$pa^{Exhib} = g(vs, mg, cr^{vis}, ex)$$

The personaliser needs to make the best possible compromise to satisfy the **Objectives** of the **co-existing stakeholders** while respecting environmental **Constraints**.



Constrained multi-objective optimization problem

The RecSys pipeline: A case-study approach

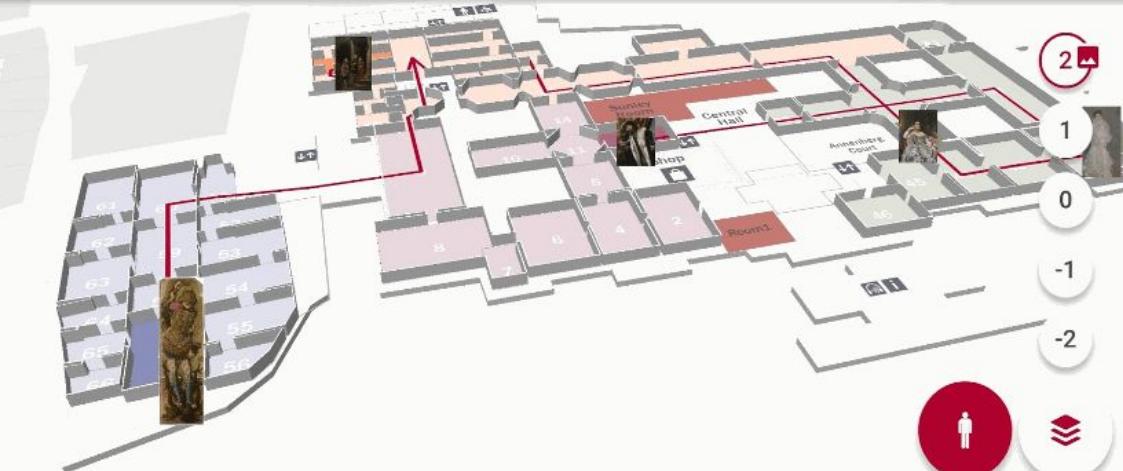


Task: Design a **Personalised Visual Art Recommendation** engine for the National Gallery, London

1. POI (painting) Recommendation

2. Path Recommendation

Contemporary Style and Fashion





The HC RecSys Pipeline

Data
Pre-processing



Model
Training

Post
Processing

Evaluation



- Sort
- Filter
- Recommend



Multi-Stakeholder aware RecSys



Data
Pre-processing



New Visitor



THE COLD START PROBLEM

Query User (Profiling)

1. Rate few paintings
2. Popular paintings
3. Visiting style
4. Available time ...

Multi-Stakeholder aware RecSys



Data
Pre-processing



Task
Personalised
Recommendation

Model
Training

Good representation of
the data!

$R^{m \times m}$

1	0.77	0.57	0.54	0.37	0.46	0.45	0.44	0.46	0.37	0.63	0.66	0.59	0.54	0.59	0.52
0.77	1	0.69	0.68	0.54	0.56	0.61	0.53	0.5	0.46	0.74	0.85	0.66	0.58	0.67	0.6
0.57	0.69	1	0.92	0.34	0.39	0.45	0.4	0.43	0.45	0.48	0.59	0.57	0.62	0.67	0.59
0.54	0.68	0.92	1	0.37	0.38	0.5	0.44	0.42	0.41	0.47	0.59	0.55	0.6	0.66	0.58
0.37	0.54	0.34	0.37	1	0.62	0.55	0.51	0.48	0.52	0.55	0.62	0.42	0.38	0.39	0.39
0.46	0.56	0.39	0.38	0.62	1	0.58	0.54	0.49	0.6	0.53	0.7	0.47	0.38	0.39	0.34
0.45	0.61	0.45	0.5	0.55	0.58	1	0.7	0.39	0.45	0.57	0.65	0.58	0.47	0.54	0.45
0.44	0.53	0.4	0.44	0.51	0.54	0.7	1	0.28	0.39	0.44	0.57	0.6	0.48	0.47	0.39
0.46	0.5	0.43	0.42	0.48	0.49	0.39	0.28	1	0.65	0.49	0.52	0.47	0.37	0.4	0.37
0.37	0.46	0.45	0.41	0.52	0.6	0.45	0.39	0.65	1	0.5	0.57	0.47	0.41	0.44	0.42
0.63	0.74	0.48	0.47	0.55	0.53	0.57	0.44	0.49	0.5	1	0.82	0.53	0.43	0.58	0.51
0.66	0.85	0.59	0.59	0.62	0.7	0.65	0.57	0.52	0.57	0.82	1	0.61	0.53	0.66	0.61
0.59	0.66	0.57	0.55	0.42	0.47	0.58	0.6	0.47	0.47	0.53	0.61	1	0.7	0.53	0.45
0.54	0.58	0.62	0.6	0.38	0.38	0.47	0.48	0.37	0.41	0.43	0.53	0.7	1	0.53	0.46
0.59	0.67	0.67	0.66	0.39	0.39	0.54	0.47	0.4	0.44	0.58	0.66	0.53	0.53	1	0.9
0.52	0.6	0.59	0.59	0.39	0.34	0.45	0.39	0.37	0.42	0.51	0.61	0.45	0.46	0.9	1

- If a user likes painting A find paintings B, C, D that are similar to A.

1. Profiling

New Visitor



- List of paintings rated $P^u = \{P_1, P_2, \dots, P_n\}; P^u \in P$
- Rating of P^u , $W^u = \{w_1, w_2, \dots, w_n\}$
- Available time T_{ava}
- Visiting style (Ant, butterfly, fish, grasshopper)
- Crowd tolerance $C_t(u)$
- $(\beta, \lambda, \varepsilon)$ Popularity, Fatigue and Diversity tolerance

Museum



- Similarity matrix from LDA/BERT/ResNet
- Opening hours
- Crowd capacity
- Curated Stories
- Rules regarding movement in the physical space.

1. POI recommendation → 1.1 Matching User Preferences



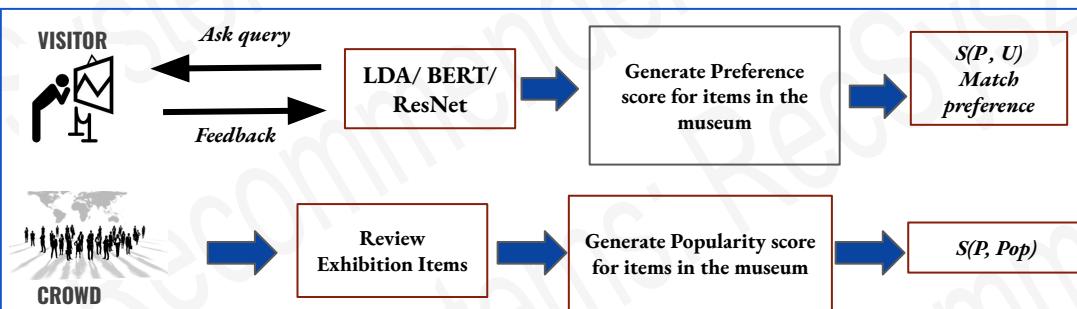
- In addition to unique personal preferences users also have different tendency to be interested in visiting famous paintings. Hence, we introduce a popularity score $S(p, Pop)$ for all the paintings in the dataset. This score is based on public review (**Crowd**) from National Gallery website.

- By taking into account the ***preference of the user*** and also the ***crowd opinion*** we generate an aggregate preference score $S(P)$ for the paintings in the dataset.

$$S(P) = \alpha S(P, U) + \beta S(P, Pop)$$

- β is user provided hyper parameter determining user's interest to see popular items.

$$\alpha = 1 - \beta$$



1. POI recommendation →

1.2 Matching Curator's Goal



- The exhibition curator might have different goals related to the point of interests to be presented for visitors.
- In this case study the curator's goal is to increase the number curated stories presented to visitors.

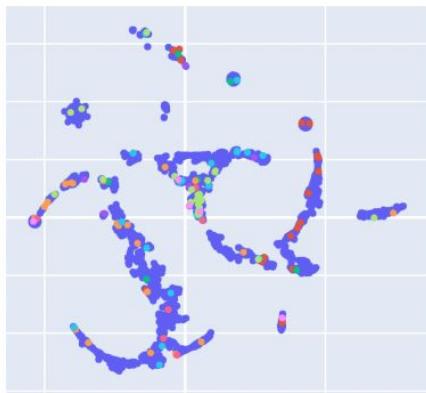
In the NG dataset we have **8 curated stories**. each story is linked to a unique set of paintings.

1. Women's Lives,
2. Contemporary Style and Fashion,
3. Water,
4. Women Artists and Famous Women,
5. Monsters and Demons,
6. Migration: Journeys and Exile,
7. Death, Battles and Commanders,
8. Warfare.

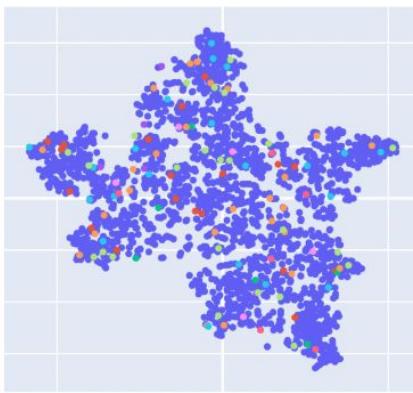
Multi-Stakeholder aware RecSys



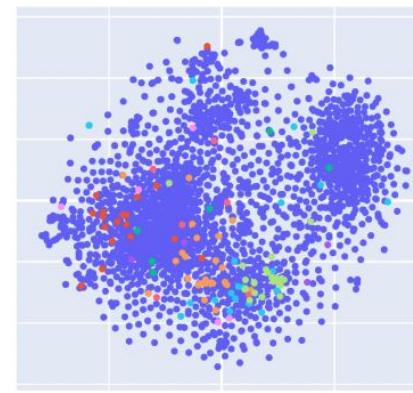
BERT



LDA



ResNet



Story groups

- Uncategorised
- Water
- Migration_Journeys_and_Exile
- Battles_and_Commanders
- Monsters_and_Demons
- Contemporary_Style_and_Fashion
- Death
- Womens Lives
- Warfare

Latent space projection (t-SNE) of the curated story groups

1. POI recommendation →

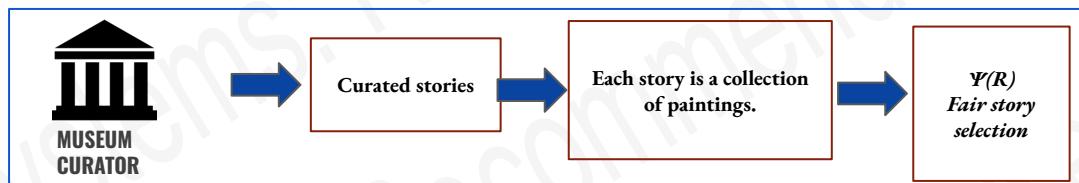
1.2 Matching Curator's Goal



- Increasing the number curated stories in the recommendation means fairly selecting the paintings from each story.
- We define a fair story selection function $\Psi(R)$.
- The function $\Psi(R)$ rewards a typical diversity of stories in the recommendation set.

$$\Psi(R) = \sum_{i=1}^K \sqrt{\sum_{p \in S_i \cap R} \gamma_p}$$

- $S_i, i = 1, \dots, K$ is the story-partition of the dataset.
- R is the recommendation set
- γ_p is a representativeness score of story group carried by painting p in the recommendation set.

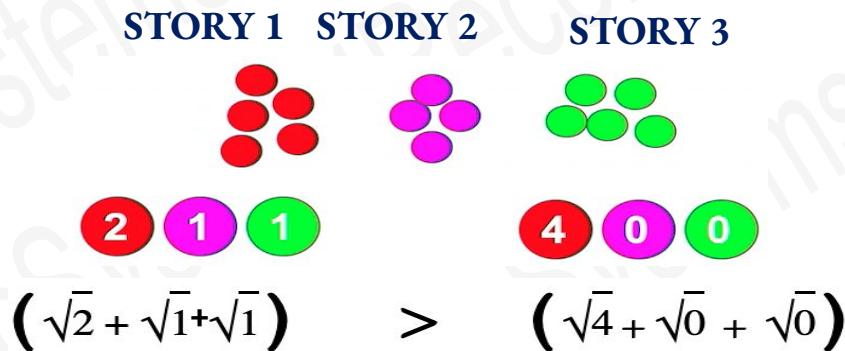


1. POI recommendation →

1.2 Matching Curator's Goal



$$\Psi(R) = \sum_{i=1}^K \sqrt{\sum_{p \in Si \cap R} \gamma_p}$$



Representative & Informative Query Selection Yilmaz et al. SIGIR2015.

1. POI recommendation →

Recommend a set R of r paintings

$$R(u) =$$

Policy 1: Maximize User Preference score.

- $\text{argmax } \sum_{a=1}^R S(P_a)$

Policy 2: Maximize the number of Curated stories.

- $\text{argmax } \Psi(R) = \text{argmax }$

$$\left(\sum_{i=1}^K \sqrt{\sum_{p \in Si \cap R} \gamma_p} \right)$$

$R(u)$

Respect time
constraint

- $\text{argmax} \left(1 - \varepsilon \left(\sum_{a=1}^R S(P_a) \right) + \varepsilon \left(\sum_{i=1}^K \sqrt{\sum_{p \in Si \cap R} \gamma_p} \right) \right)$

S.t

$$\sum_{a=1}^R T_{\text{v}}(P_a) \leq T_{\text{ava}}$$

User's tolerance
to diversity

2. Path recommendation

We now have a recommendation Set of Paintings R.

- Project the painting from R on the Venues (Rooms).

The initial **Optimal route** should lead the visitor in the *least expensive path* and *highest relevance*.

Such that:

- *The total sum of estimated visiting times and travel time should not exceed the available time of the visitor.*
- *The crowd size in the selected rooms should not exceed the crowd tolerance threshold of the visitor.*



2. Path recommendation

Depending on the user **Relevance** could mean two things:

1. Quality: Visit the most interesting paintings.

- We define a quality score $\Theta(v_i)$ which is the sum of the scores of all the recommended paintings in venue i.

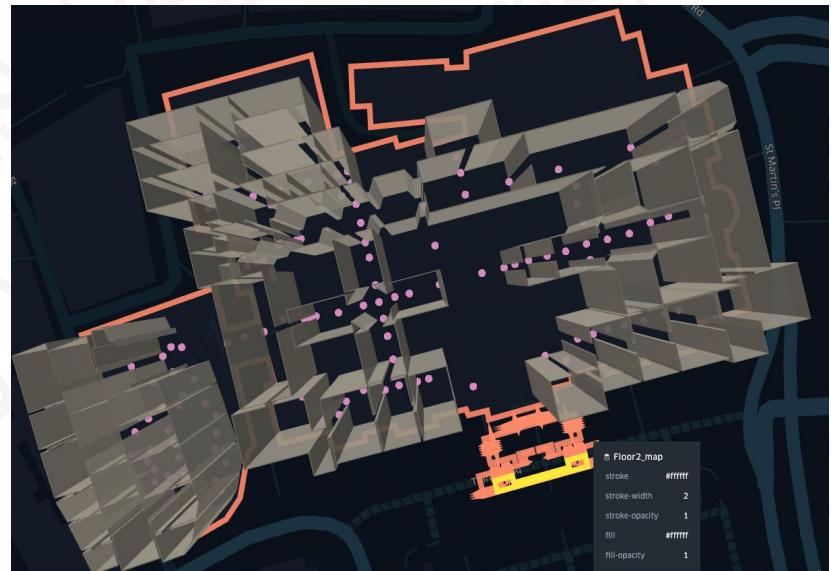
$$\bullet \quad \Theta(v_i) = \sum_{i=1}^h S(P_i)$$

- h is the total number of recommended paintings in Venue V

2. Quantity: Visit as many paintings as possible.

- We define a quantity score of every venue

$$\delta(v_i) = b_i$$





2. Path recommendation



*Recommend a path $PT(u)$
(sequence of M rooms)*

Policy 1: Maximize relevance score $S(R)$

- $\text{argmax } \sum_{a=1}^M \Theta(v_a) \quad \text{if Quality} > \text{Quantity}$
- $\text{argmax } \sum_{a=1}^M \delta(v_a) \quad \text{otherwise}$

Policy 2: Minimize travel distance

$$\bullet \text{ argmin } \sum_{a=1}^M \text{dist}(v_a, v_{a+1})$$

Subject to:

1. Time constraint:

$$\bullet \sum_{a=1}^M T(v_a) + Tt \leq T_{ava}$$

$$Tt = \sum_{a=1}^M Tt(v_a, v_{a+1})$$

2. Crowd constraint:

$$\bullet \forall v_a ; 1 \leq a \leq M$$

$$Cr_s(v_a) \leq Cr_t(u)$$

2. Path recommendation

*Recommend a path $PT(u)$
(sequence of M rooms)*

$$\text{argmax } \left(\lambda \sum_{a=1}^M S(v_a) + (1-\lambda) \left(\frac{1}{\sum_{a=1}^M \text{dist}(v_a, v_{a+1})} \right) \right)$$

Maximize total Score

$PT(u) =$

Respect time constraint

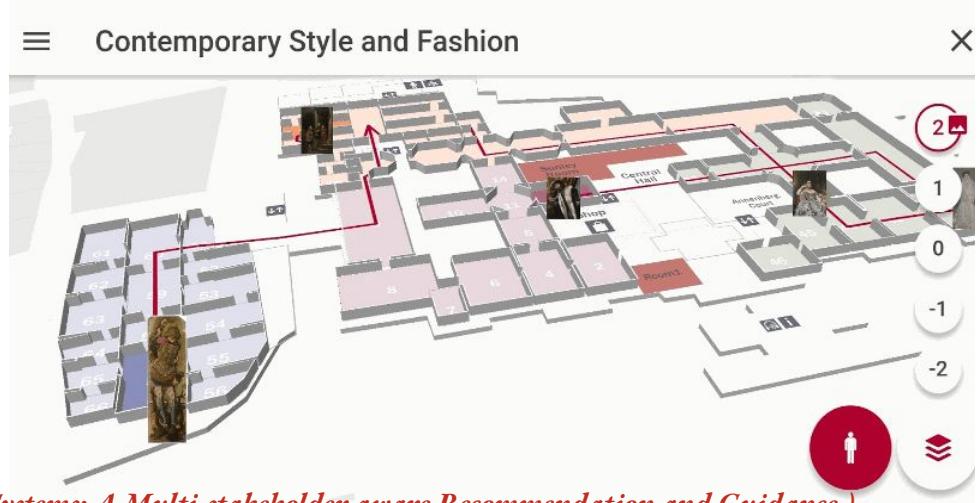
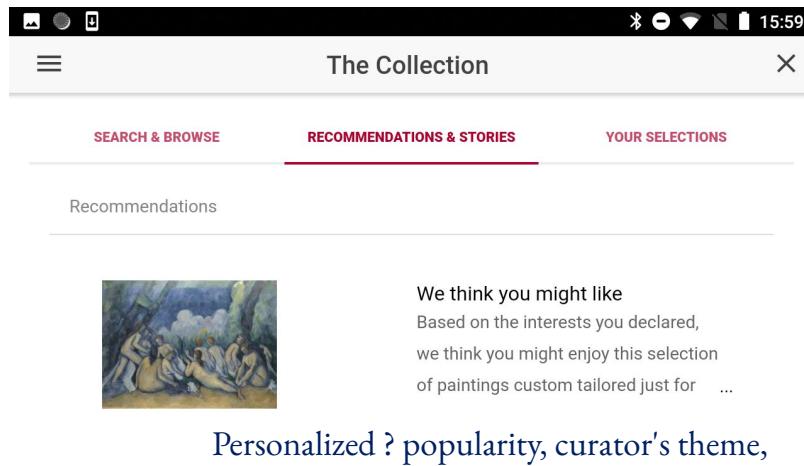
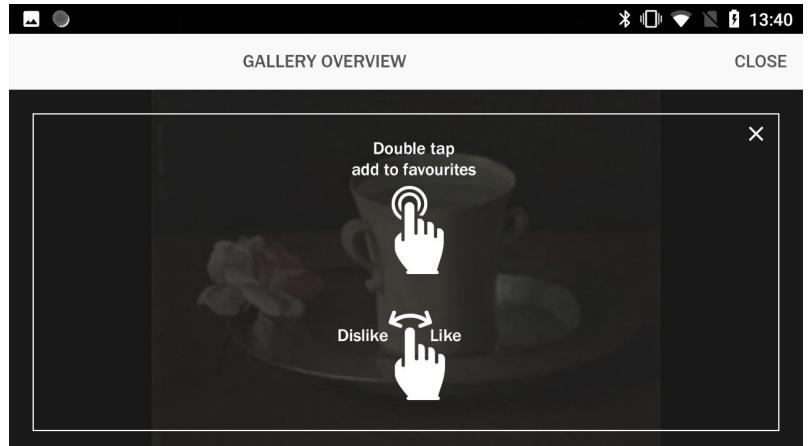
Respect Crowd tolerance

$$Tv(v_a) + Tt \leq T_{ava}$$

$$Tt = \sum_{a=1}^M Tt(v_a, v_{a+1})$$

- $\forall v_a ; 1 \leq a \leq M$
- $$Cr_s(v_a) \leq Cr_t(u)$$

Minimize total travel distance



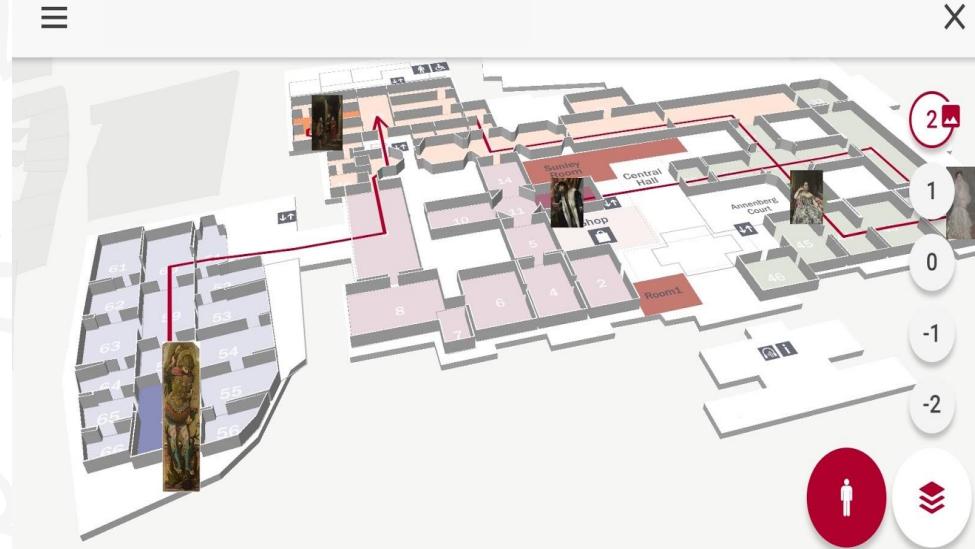
Multi-Stakeholder aware RecSys



Mobile app

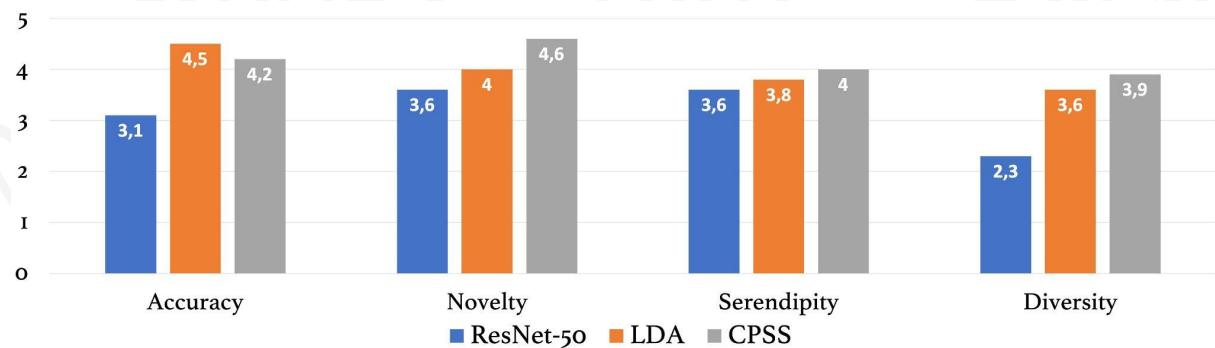


Mixed reality glass



Multi-Stakeholder aware RecSys

Baseline Single objective **Vs** Multi-objective



Yilma et al. (UMAP '21)

Multi-Stakeholder aware RecSys



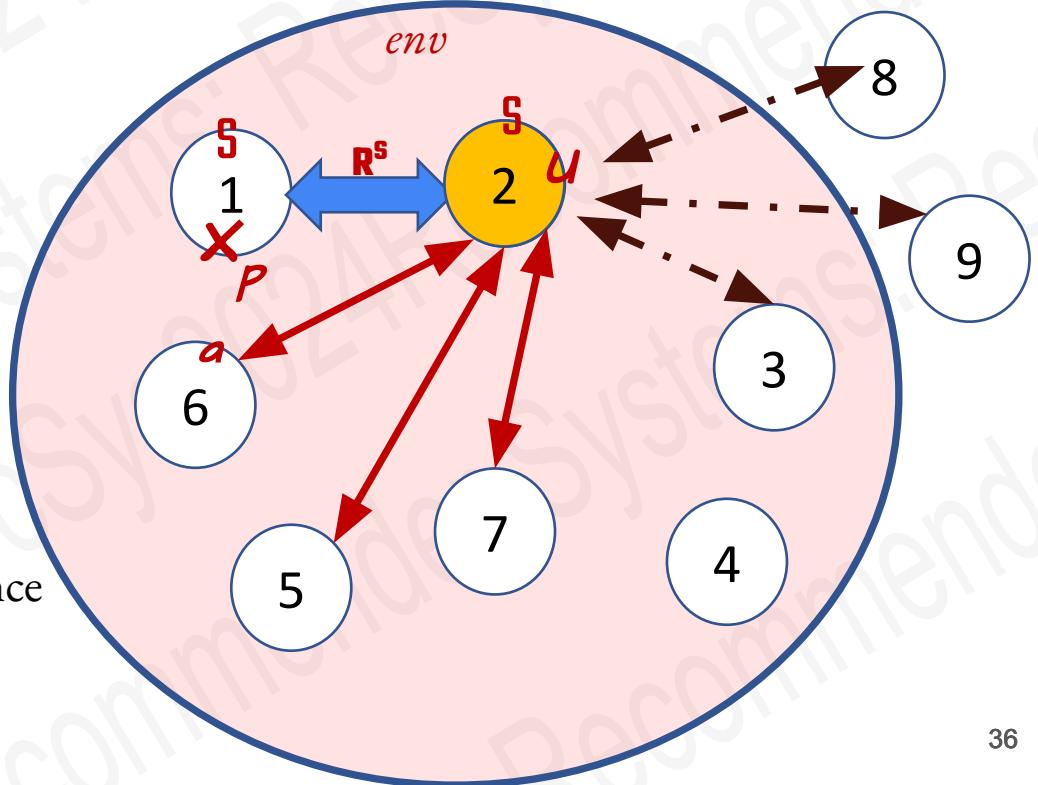
- Understanding the Problem setting.
- Identifying stakeholders (**Competing objective or Constraints**).
- Prioritizing objectives.

Formulating a RecSys Problem

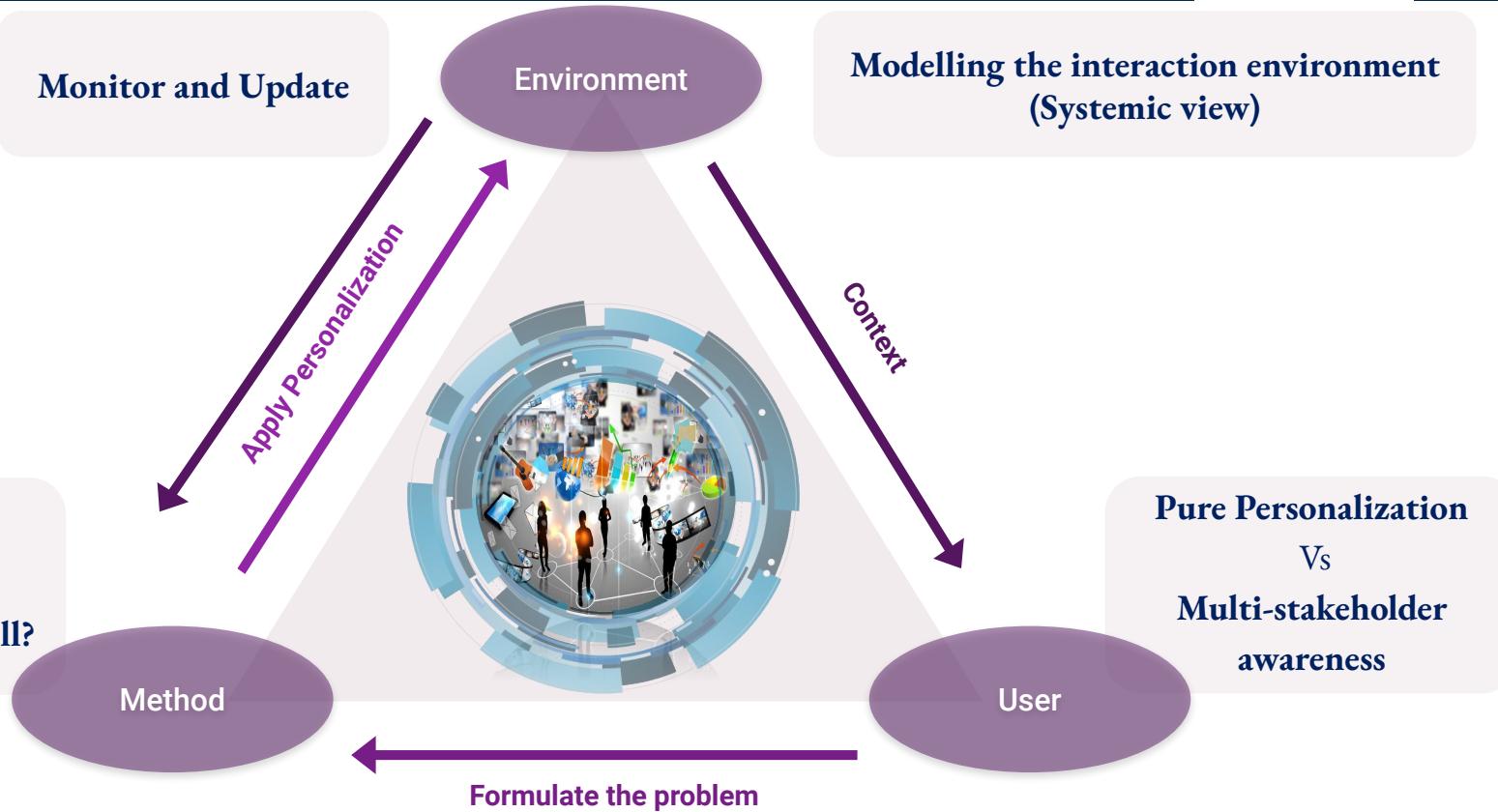


- Smart system environment env ,
- **Personalisation** is a function of a social component **S** of a system.
- **Personaliser**(x_{pa});
- **User**(U)
- **Crowd**(Cr): direct influence
- **Context elements**(Cx): indirect influence

$$Pa^{coss} = f(u, x_{pa}, cr, cx, env)$$



Design Guidelines: Personalization in CPSS



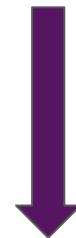
Downstream Applications



Cultural Heritage



Visual Art Recsys
Engines



Art Therapy



Healthcare



Intensive Care Unit (ICU) Experience of patients



- Delirium
- Post-Intensive Care Syndrome (PICS)

Post-Intensive Care Syndrome (PICS)



PHILIPS

Healthcare

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DIGITAL NATURE

80% of patients released from the ICU suffer from
Post-Intensive Care Syndrome (PICS)

LONG-TERM IMPAIRMENT



PHYSICAL



MENTAL



COGNITIVE

- Anxiety
- Depression
- Post-Traumatic Stress Disorder (PTSD)

Psychotherapy

78 Weeks

Average time for significant improvement



Post-Intensive Care Syndrome (PICS) Treatments



PHILIPS

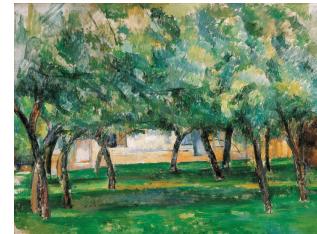
Healthcare

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DIGITAL NATURE

- Therapeutic effects of visual nature experiences → Positive distraction

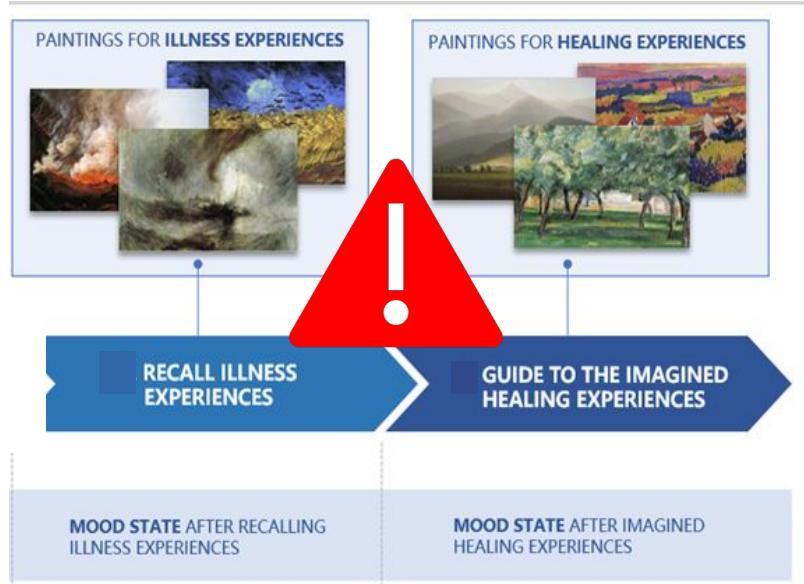
Strong link between nature and wellbeing



**Art as a visual therapy
outside hospital settings**

- To treat PTSD

Art as a visual therapy for PICS Treatment



PICS Survivors

Unique ICU experience



Clinicians

- limited art knowledge
- Large size of exploration space

PHILIPS

Healthcare

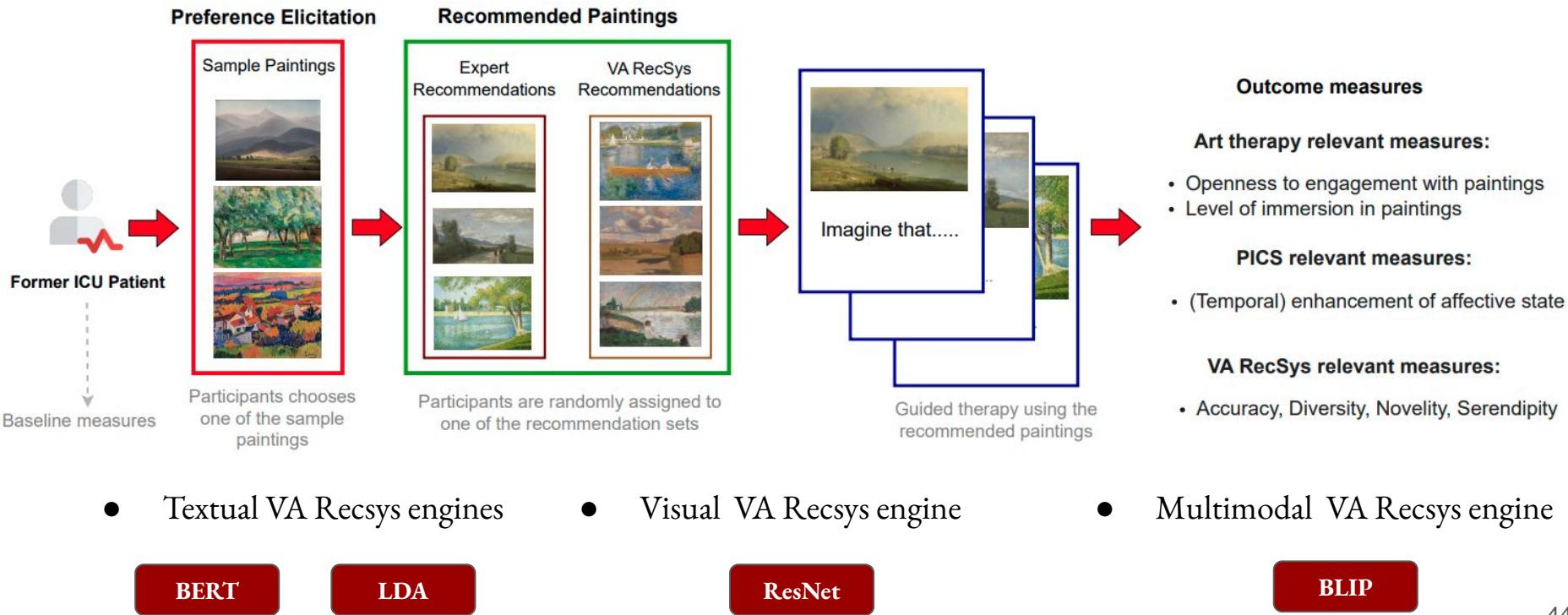
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DIGITAL NATURE



● Personalized VA RecSys

Art therapy approach for PICS prevention and treatment



Ensuring a safe and sensitive Deployment: Pilot test

Expert evaluation of VA RecSys engines

		Fusion BLIP	Image ResNet	Text BERT	Text LDA
Expert 1 (Affective Design, ICU research, +10)	Painting 1	2	3	1	1
	Painting 2	3	2	3	1
	Painting 3	2	3	2	1
Expert 2 (Affective Design, +10)	Painting 1	3	2	2	1
	Painting 2	3	2	1	2
	Painting 3	2	4	2	1
Expert 3 (Affective Design, +10)	Painting 1	2	4	1	1
	Painting 2	1	1	2	4
	Painting 3	2	3	1	1
Expert 4 (ICU Nurse, +10)	Painting 1	1	4	2	2
	Painting 2	4	2	3	3
	Painting 3	2	3	2	1
Total		27	33	22	19

They were shown 3 paintings from each of the VA RecSys engines for all sample paintings



"There are ruins and destructions which are quite negative."
(E2)



"It reminds of a storm, and an overly abstract style is not recommended for healing paintings." (E1)

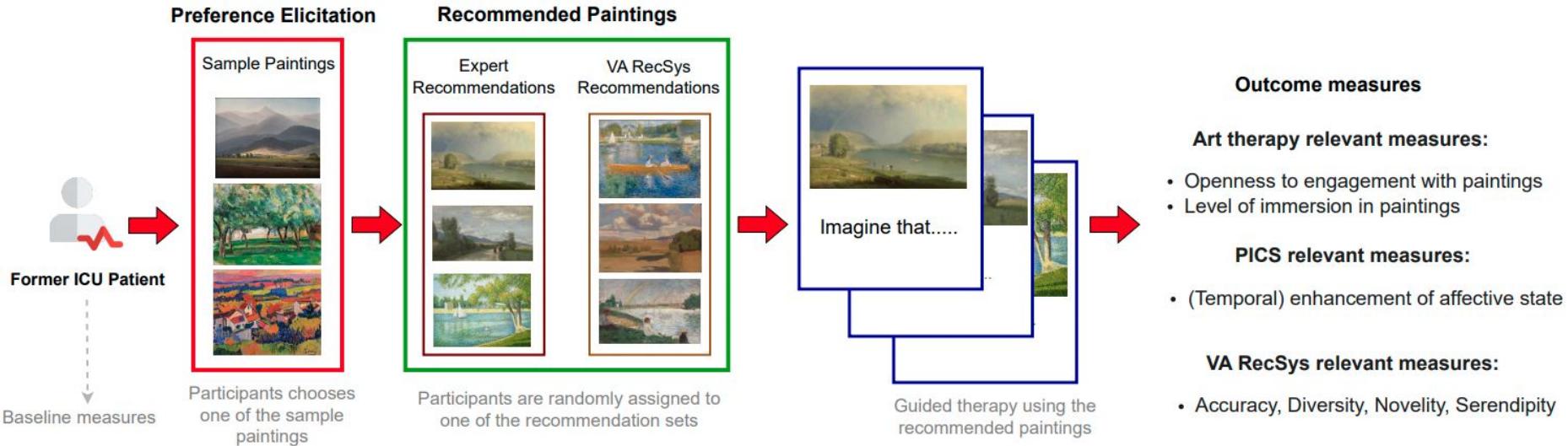
Ensuring a safe and sensitive Deployment: Pilot test

Expert evaluation of VA RecSys engines

Sample Paintings	Expert		Visual		MultiModal	
						
						
						

Top-2 recommendations for each sample painting from expert-validated engines.

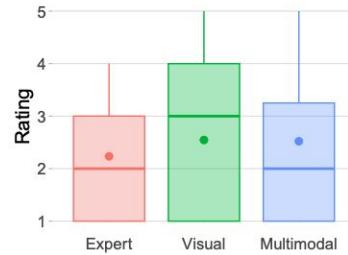
User Study: Guided Art Therapy with Post ICU patients



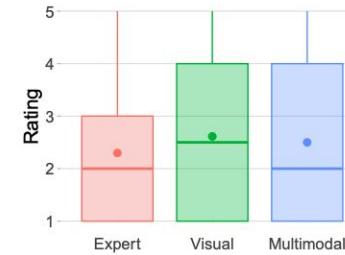
- N = 150 (between-subjects design) former ICU patients
- 50 per engine (Expert, Visual and Multimodal)

User Study: Guided Art Therapy with Post ICU patients

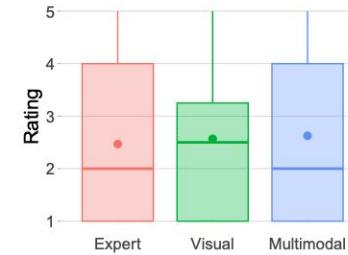
Art Therapy & Va RecSys relevant measures



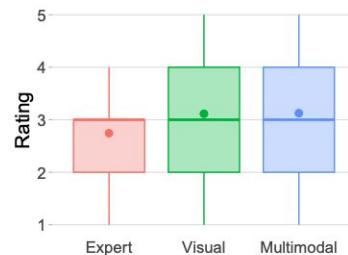
(a) Immersion



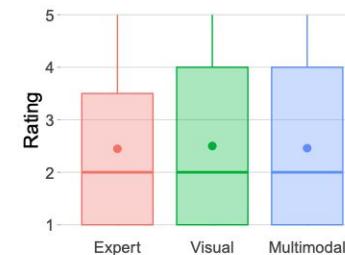
(b) Engagement



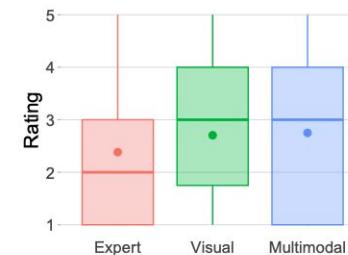
(c) Accuracy



(d) Diversity



(e) Novelty

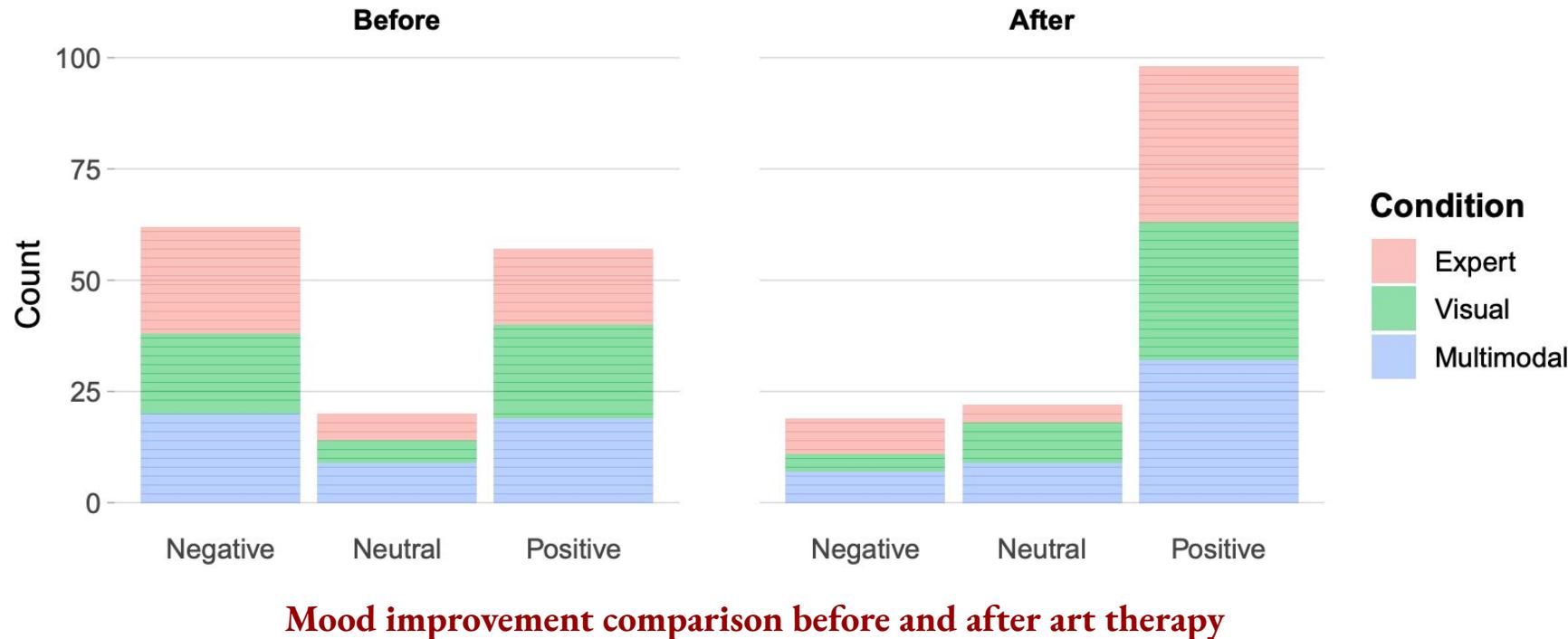


(f) Serendipity

Distribution of user ratings (Dots denote mean values.)

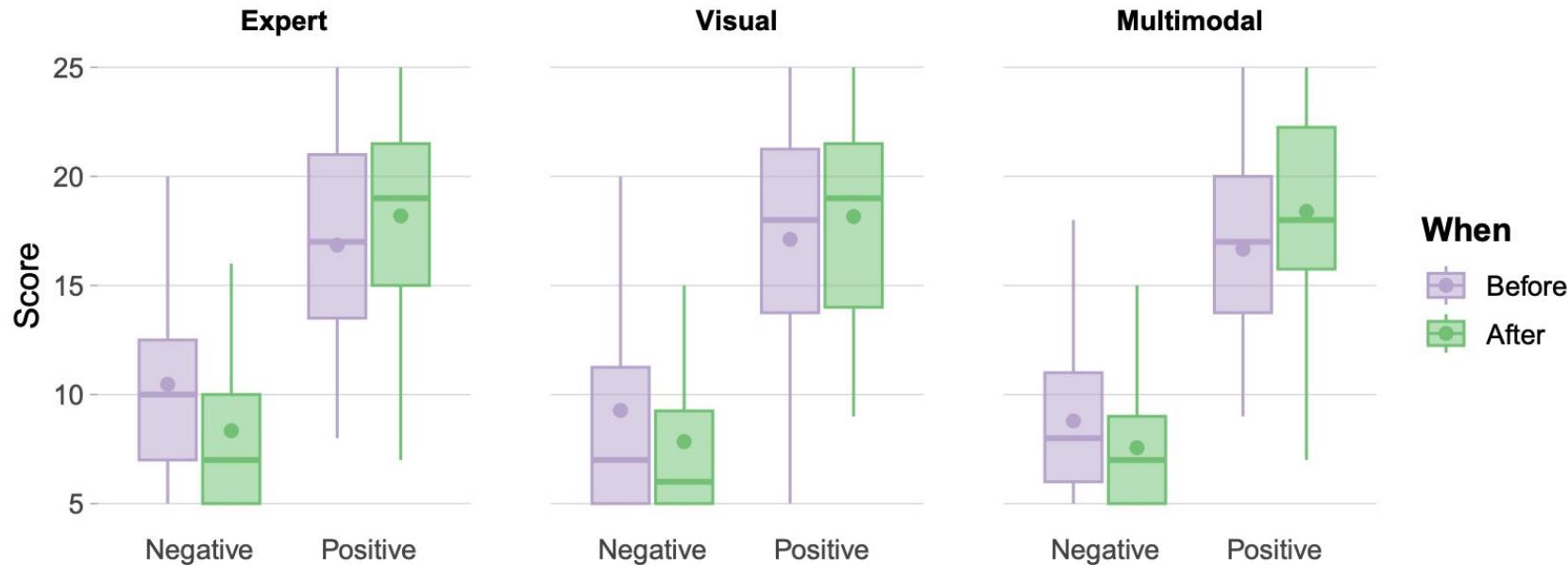
User Study: Guided Art Therapy with Post ICU patients

PICS relevant measures



User Study: Guided Art Therapy with Post ICU patients

PICS relevant measures

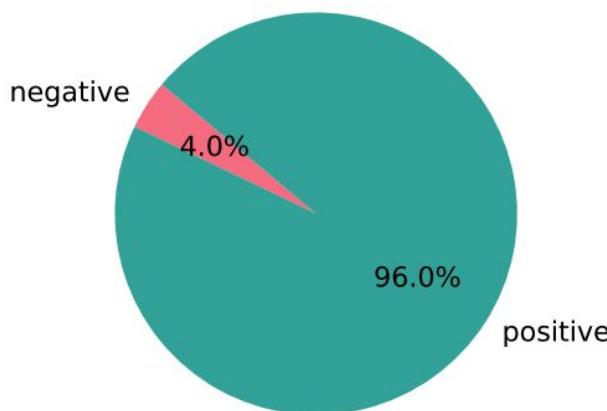


Emotion score changes according to the Positive Affect Negative Affect Schedule (PANAS) Scale.

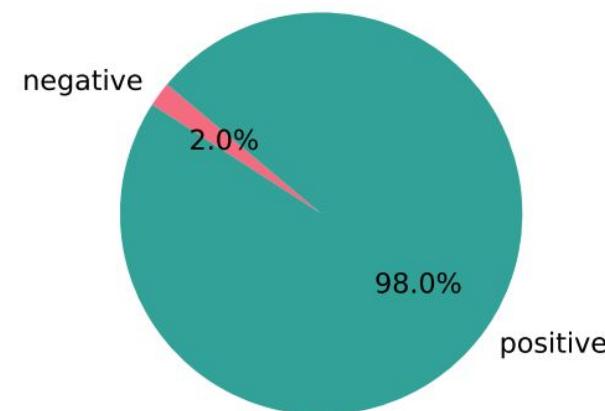
User Study: Guided Art Therapy with Post ICU patients

Participants' Post Therapy Reflection

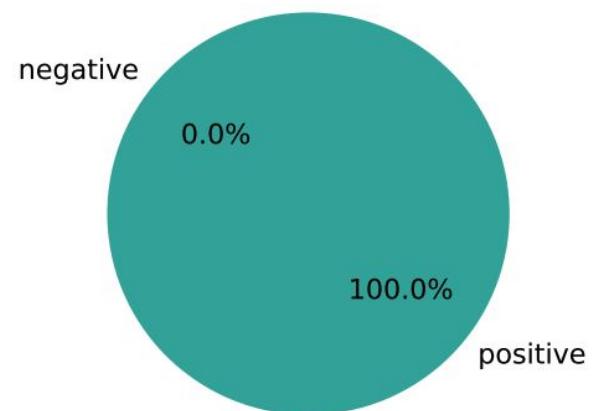
Expert Group Sentiments



Visual Group Sentiments



Multimodal Group Sentiments



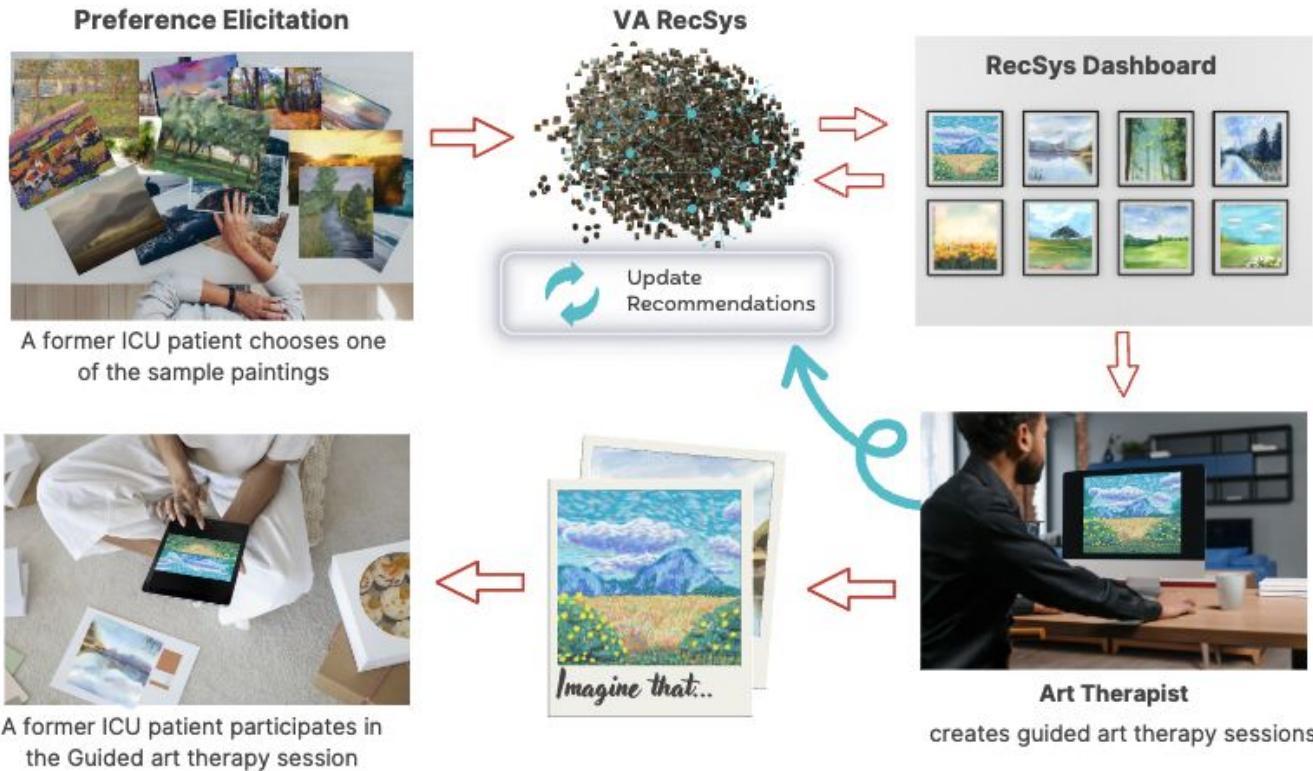
Sentiment analysis of user reflections per group

User Study: Guided Art Therapy with Post ICU patients

Qualitative evaluation through Reflexive Thematic analysis (RTA)



Human-in-the-Loop



Potential Beyond PIKS Prevention & Treatment



Philips VitalSky



use



Common Issues and Challenges in RecSys

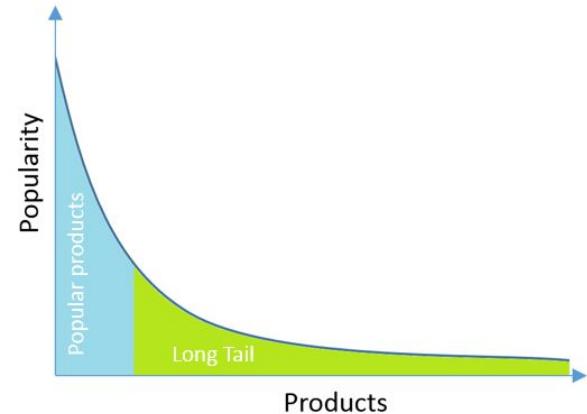
RecSys Issues & Challenges

- **Cold start**

→ Sparsity

$$\text{Sparsity} = \frac{\# \text{ ratings}}{\text{total } \# \text{ cells}}$$

- Ratings
- Time spent
- Product clicked



- **Diversity**



RecSys Issues & Challenges

- **Privacy**: Third party, sensitive private information

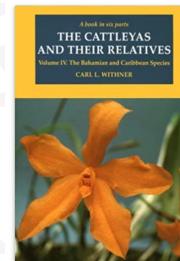
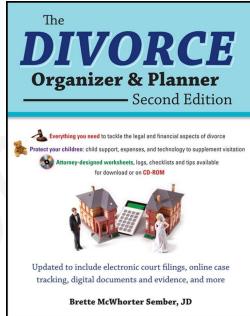
→ **Collaborative Filtering**: users willingly disclose their preferences to the system in the hope of getting useful recommendations.



Likes growing Orchid



Bought



Customers who viewed this item also bought

The DIVORCE Organizer & Planner – Second Edition

Updated to include electronic court filings, online case tracking, digital documents and evidence, and more

Brette McWhorter Sember, JD

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Eddie M Sanchez Publishing

4.5 stars based on 22 reviews

Paperback \$6.99 \$17.27 shipping

child custody log book

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Eddie M Sanchez Publishing

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Lara Carter

4.5 stars based on 239 reviews

Paperback \$6.99 \$18.87 \$16.81 shipping

Child Custody Journal: Child Custody Visitation Planner Calendar and Co-Parenting Log Book to Plan and Record...

Charlie L. Press

4.5 stars based on 293 reviews

Paperback \$6.99 \$16.81 shipping

The Cattleyas and Their Relatives: Volume IV: The Bahamian and Caribbean Species Hardcover – April 15, 1996

by Carl L. Witthner (Author)

4.6 stars based on 3 ratings

Book 4 of 5: Cattleyas and Their Relatives

Hardcover from \$34.66

8 Used from \$34.66

See all formats and editions

Cattleyas are frequently called "the Queen of the Orchids," and Carl Witthner's passion for them started before World War II. About 12 years ago he published the first in this series of six books, which now comes to a conclusion with this final volume. The South American *Erycilla* species have not previously been the subject of a book, and the genus presents many problems and difficulties. A few of the species are known from a single herbarium specimen and may well now be extinct because of the continuing loss of habitat.



RecSys Issues & Challenges

Privacy

- Complete privacy may not be realistic → compromise on minimizing the privacy breaches
- Comes at the expense of the accuracy of the recommendations.
- Important to analyze this trade-off carefully.



RecSys Issues & Challenges



- **Adaptivity:** changing business needs
- **Robustness:** Attack/ stress
- **Scalability**

RecSys Issues & Challenges

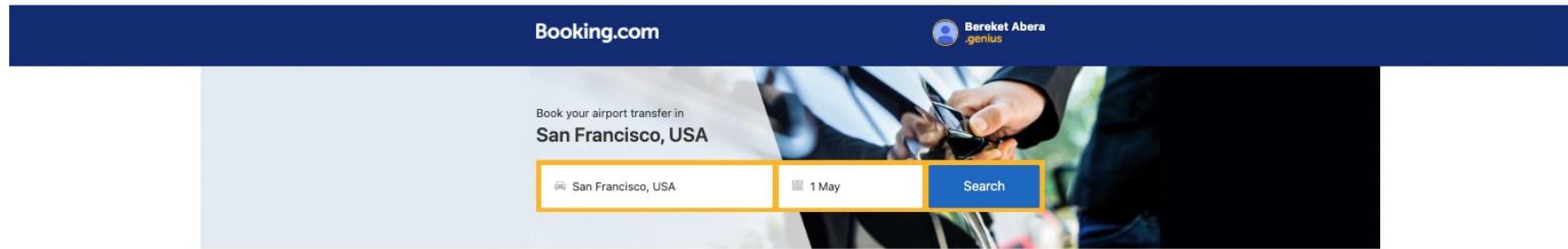
- **Proactiveness:** Predict when and how to push Recommendations ← implicit request

Bereket, book a taxi direct to Holiday Inn Express Hotel & Suites Fisherman's Wharf ➔ [Inbox](#)



Booking.com <email.campaign@sg.booking.com> [Unsubscribe](#)
to me ➔

Apr 27, 2019, 11:55 PM ⌂ ⌃ ⌁



The screenshot shows an email from Booking.com. The subject line is "Bereket, book a taxi direct to Holiday Inn Express Hotel & Suites Fisherman's Wharf". The email header includes the Booking.com logo, the recipient's name "Bereket Abera .genius", and a small profile picture. The main content features a dark blue header with the Booking.com logo and the recipient's name. Below this is a large image of two people in a car. Text on the left side of the image reads "Book your airport transfer in San Francisco, USA". Below the image is a search bar with three fields: "San Francisco, USA", "1 May", and a blue "Search" button. The body of the email starts with "Hi Bereket," followed by a message about convenient airport transfers. It lists three guarantees: "Guaranteed price", "Guaranteed pick-up", and "Tried and trusted drivers". At the bottom, there is a link "Find your ride".

Hi Bereket,

Looking for a convenient, reliable way to get to your accommodation? Your driver and car will be waiting at the airport – no unfamiliar public transport to navigate, no worries on finding the way to your stay.

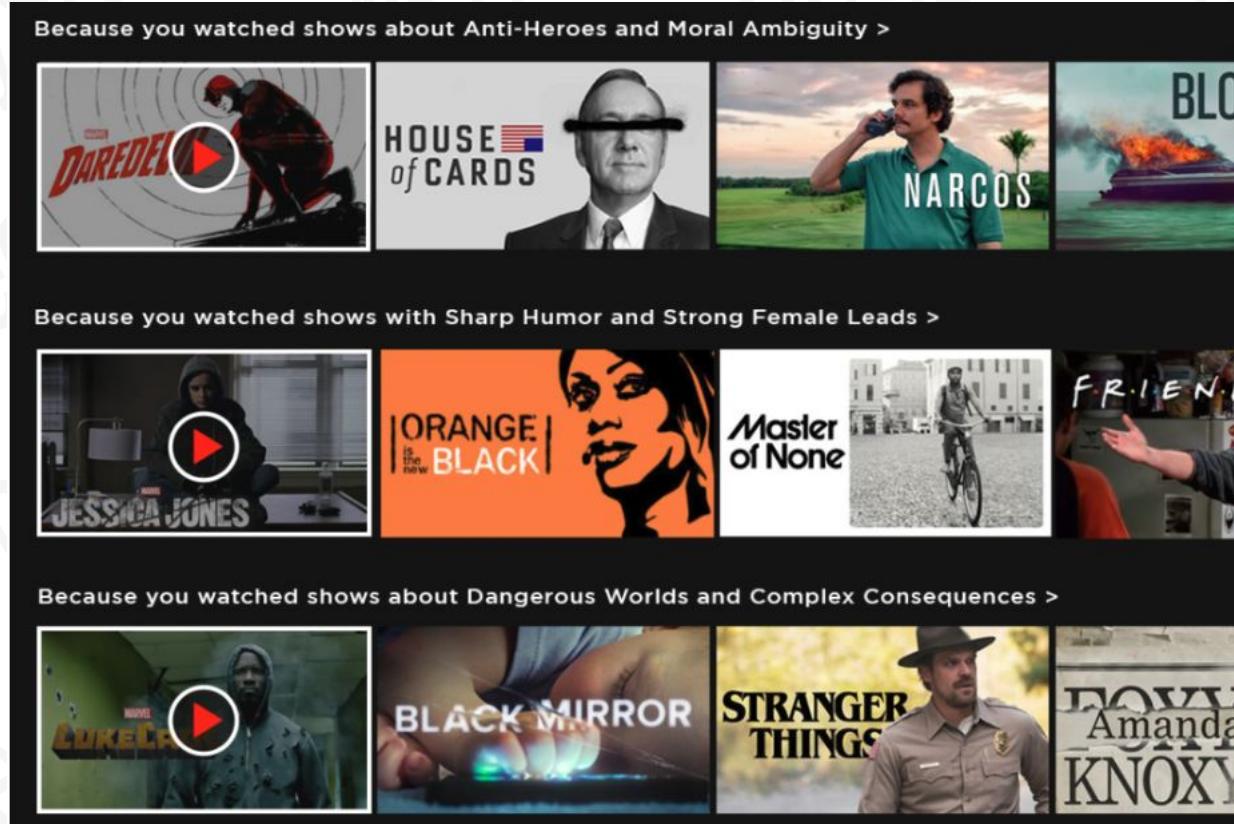
✓ **Guaranteed price** ✓ **Guaranteed pick-up** ✓ **Tried and trusted drivers**

Want to get back to the airport just as easily? Book your return journey at the same time and enjoy your holiday with one less thing to worry about.

[Find your ride](#)

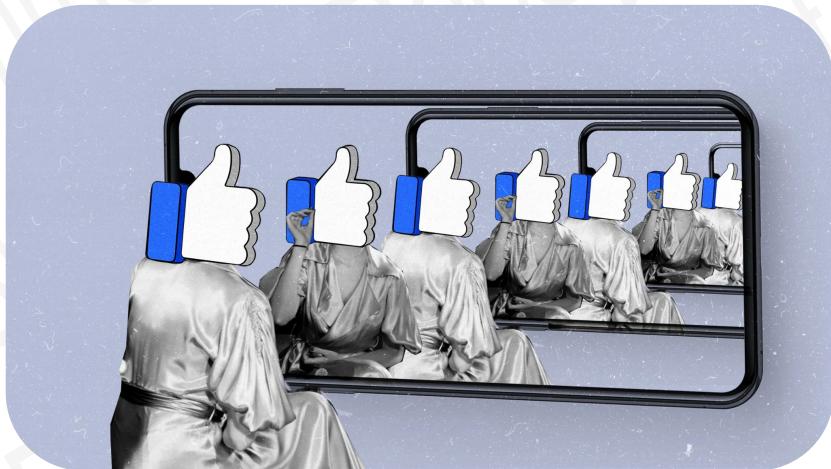
RecSys Issues & Challenges

- Explainability



RecSys Issues & Challenges

- Echo Chamber



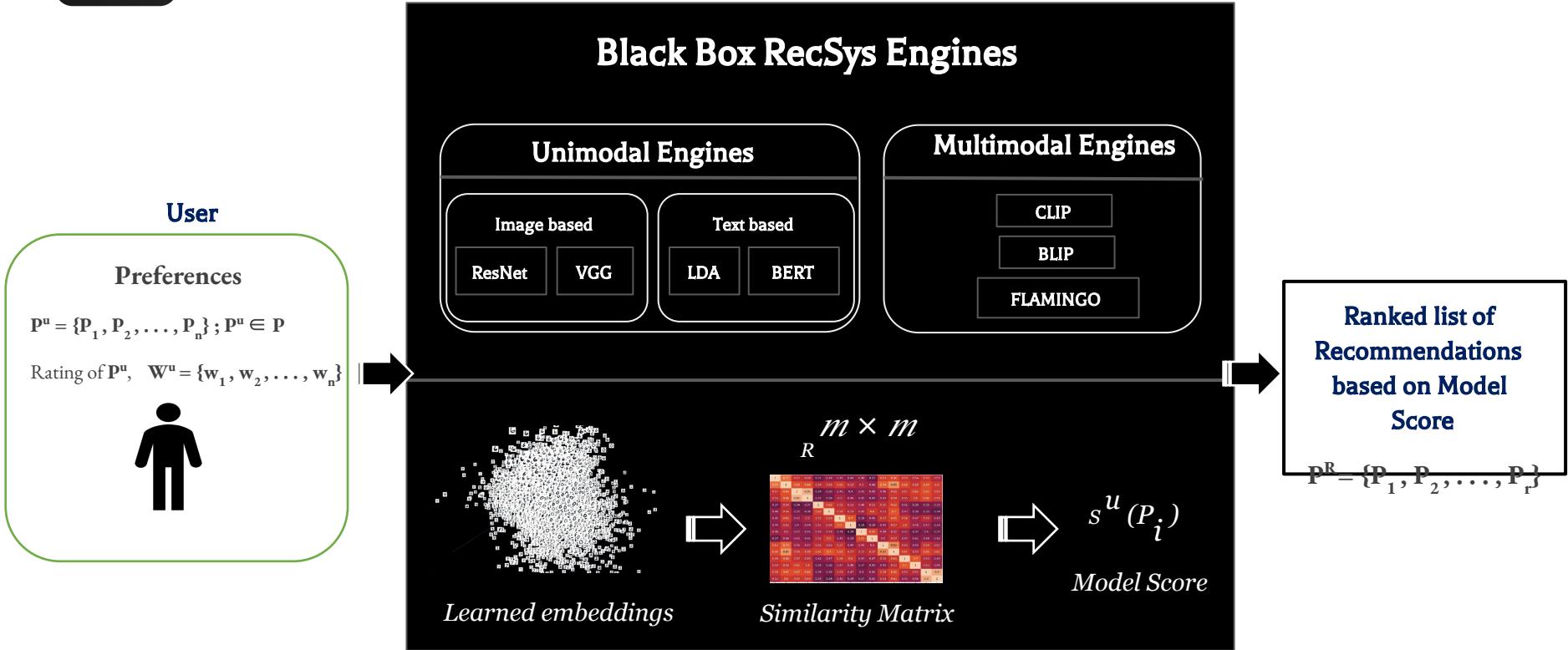
- **Filter bubbles**



- Limiting exposure to diverse perspectives.
- Reinforcing existing biases and stereotypes.



RecSys Issues & Challenges





Exploration and Controllability

User

Preferences

$$P^u = \{P_1, P_2, \dots, P_n\}; P^u \in P$$

Rating of P^u , $W^u = \{w_1, w_2, \dots, w_n\}$



Black Box
RecSys
Engines

$s^u(P_i)$
Model Score

Controlling Popularity Bias

$$S_{AG}^u(p_i) = S^u(p_i) + \beta S^{\text{pop}}(p_i)$$

Giving users the Control

Generate Recommendations





→ **Hands-on**

Reflection



Contact: bereket.yilma@uni.lu

 @bek_yilma



[Feedback form](#)