



# AI for Sustainable Recommender Systems (Vision and Challenges)

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# Outline

1. Task identification

2. Current state of the literature

+ our vision / critique / opinion about what may be important or should be improved

# Sustainable RS Task

- Mediate multiple stakeholders' goals while including environment preservation
  - users, providers, destination managers, environment ...



*stakeholder is any group or individual that can affect, or is affected by, the delivery of recommendations to users*

*stakeholders have their own goals that may not coincide with each other*

# Achieving Sustainability in RS is Hard

1. Users behaviour is hard to change

- user may ignore sustainable recommendations

2. Impact of (sustainable) RS policies is hard to estimate

- train-test split is not enough
- trustworthy A/B tests & user studies are very expensive

# Research Problems

1. Users behaviour is hard to change

- user may ignore sustainable recommendations

2. Impact of (sustainable) RS policies is hard to estimate

- train-test split is not enough
- trustworthy A/B tests & user studies are very expensive

1. Understand the mechanisms how RS changes user behaviour

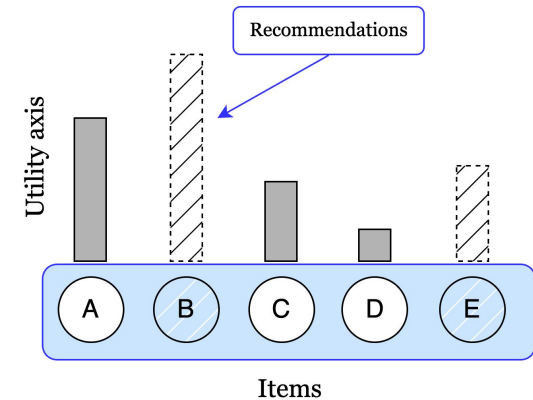
2. Implement the mechanisms into the RS policy to nudge users to desired behaviour

3. Be able to evaluate the impact of a given RS policy (w.r.t. success metrics)

# 1) Mechanisms how RS Changes User Behaviour

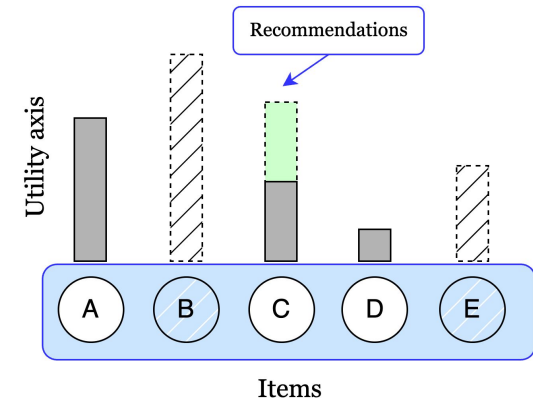
## - Increase of awareness (Aset)

- users are not aware of the full catalogue of the items
- users become aware of “new” recommended items and get a larger pool of alternatives



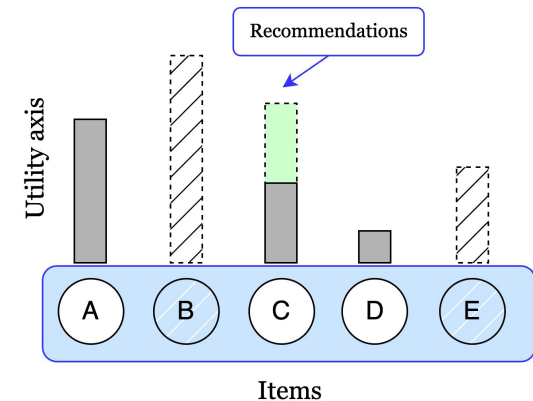
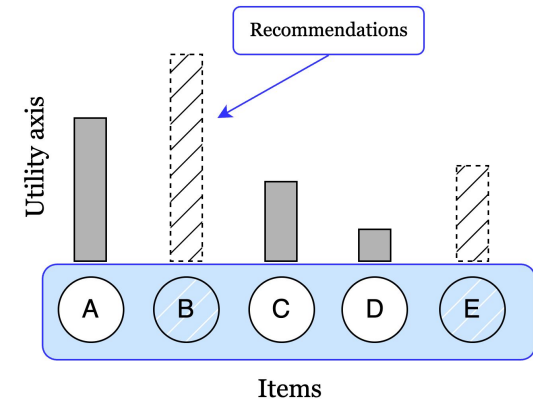
## - Salience effect

- recommended items become more salient for users
- due to persuasive properties of GUI / explanations / trust in RS



# 1) What Can Be Improved?

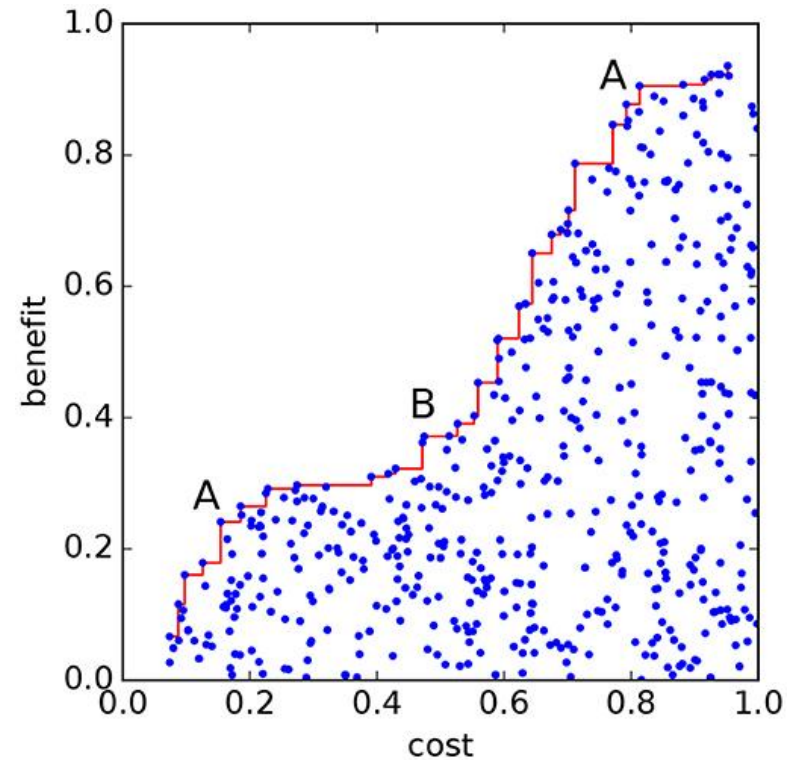
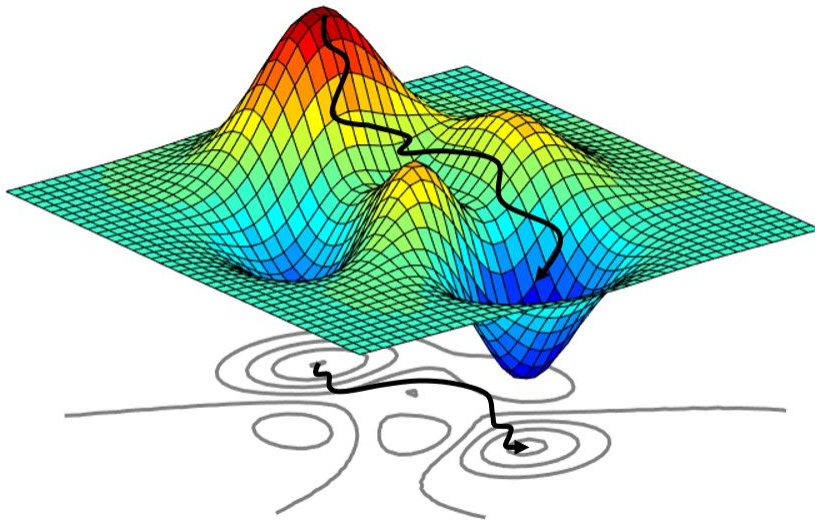
- Increase of awareness (Aset)
  - better estimate awareness Aset
  - add information about Aset into preferences learning model (when learning from implicit feedback)
- Salience effect
  - develop models of recommendation salience
  - multiplicative, additive, a mixture of both?



## 2) Algorithmic Nudging to Sustainable Behaviour

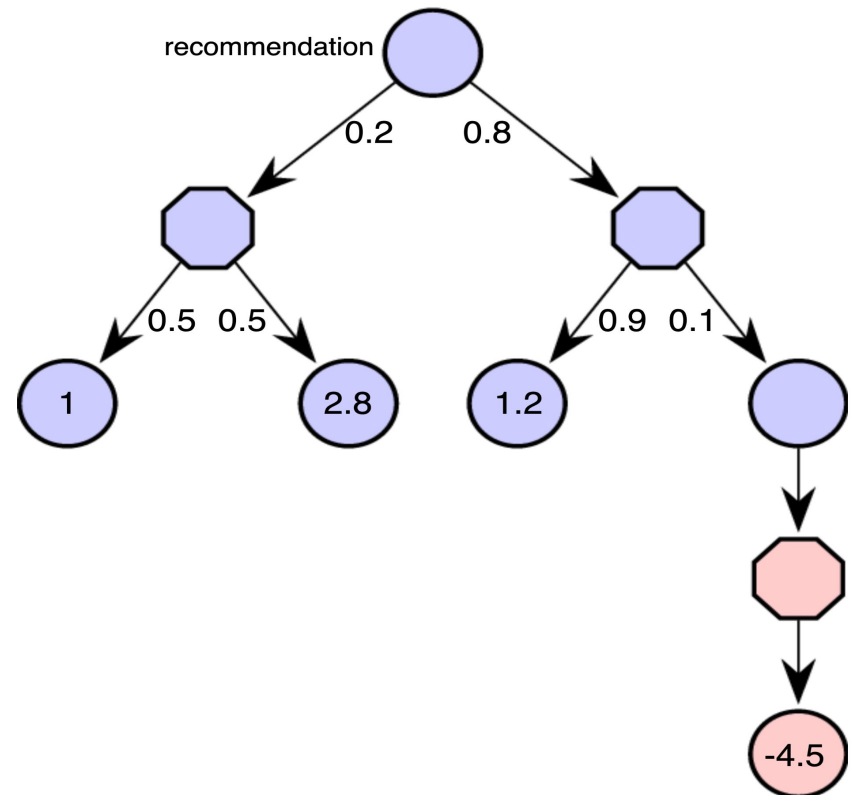
### - Algorithmic aspects of policy optimisation

- balance sustainable & relevant items ( $\text{fn}(U_1, \dots, U_k, \Theta, Z) \rightarrow \max_Z$ )
- by optimising recommendations w.r.t. exposure metrics (individual vs. global levelling)



## 2) What Can Be Improved?

- Algorithmic aspects of policy optimisation
  - integrate Aset and salience models into recommendation problem
  - optimise multistakeholder recommendations w.r.t. expected consequences rather than exposure
  - consider GUI/UX optimisation



## 2) How it Can Be Improved?

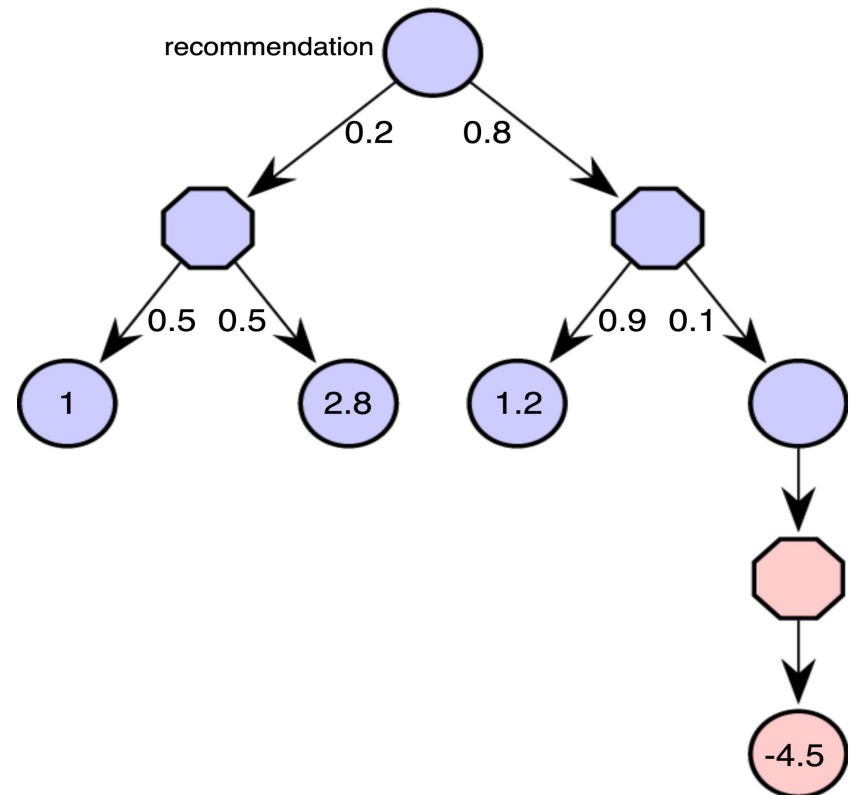
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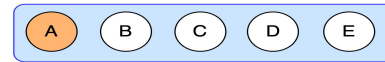
would require  
modelling individual  
users



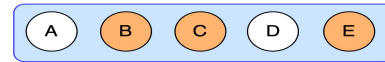
# Modelling Individual Users

- Choice modelling (based on preference and knowledge)

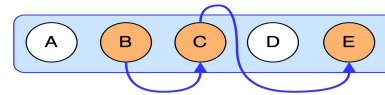
- single choice models



- multiple (bundle) choice models



- sequential decision making



- Modelling impact of recommendations on user choices

- awareness & salience effect

- ... Also users feedback modelling (like/dislike)

- experienced vs. decision utilities

All these aspects are subject of further research!

### 3) Evaluate the Impact of a Given RS Policy

- Online evaluation (A/B tests or user studies)
  - + trustworthy
  - + risky w/o preliminary “validation”
- Offline evaluation
  - + train-test split w/ or w/o unbiased techniques
  - + how to estimate the impact of the (off-policy) recommendation?
  - + counterfactual (what-if) simulations

# Environment Simulation (and A/B Test Imitation)

## Users database

- a sample of real / synthetic users

## RS policy ( $\pi$ ) to test

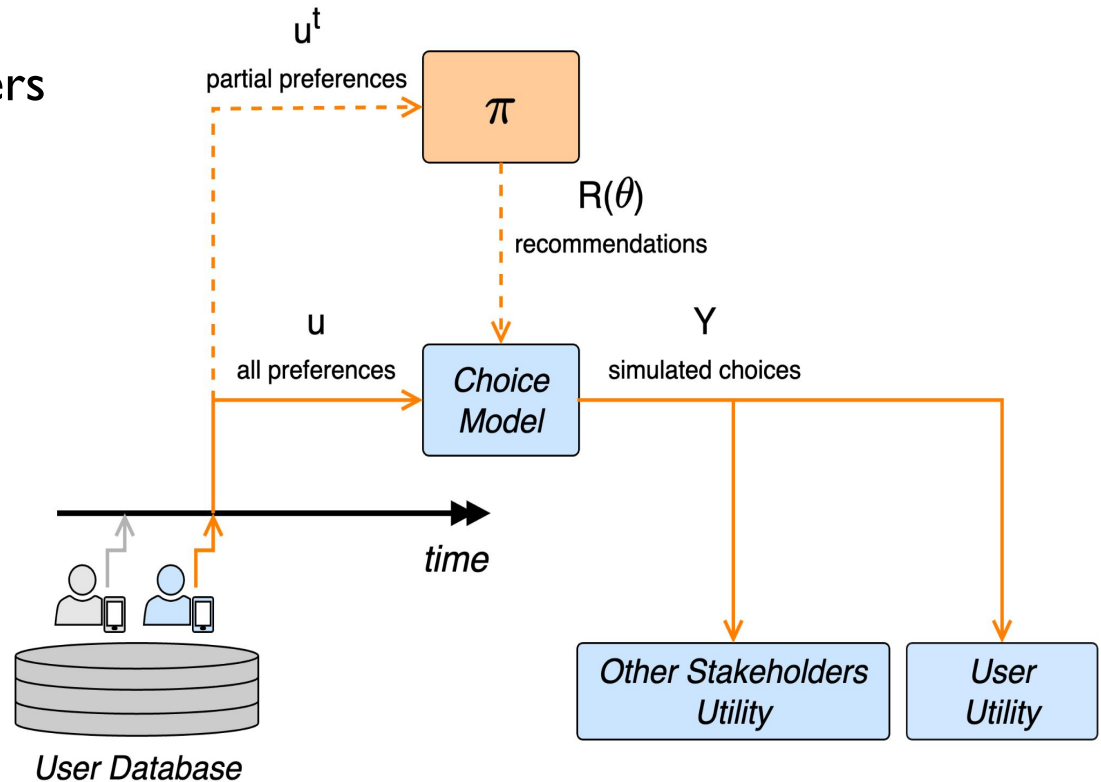
- recommends items
- can be adjusted based on  $\Theta$

## Choice/Interaction model

- how users behave
- how users interact with RS

## Success metrics

- user utility
- other stakeholders utility



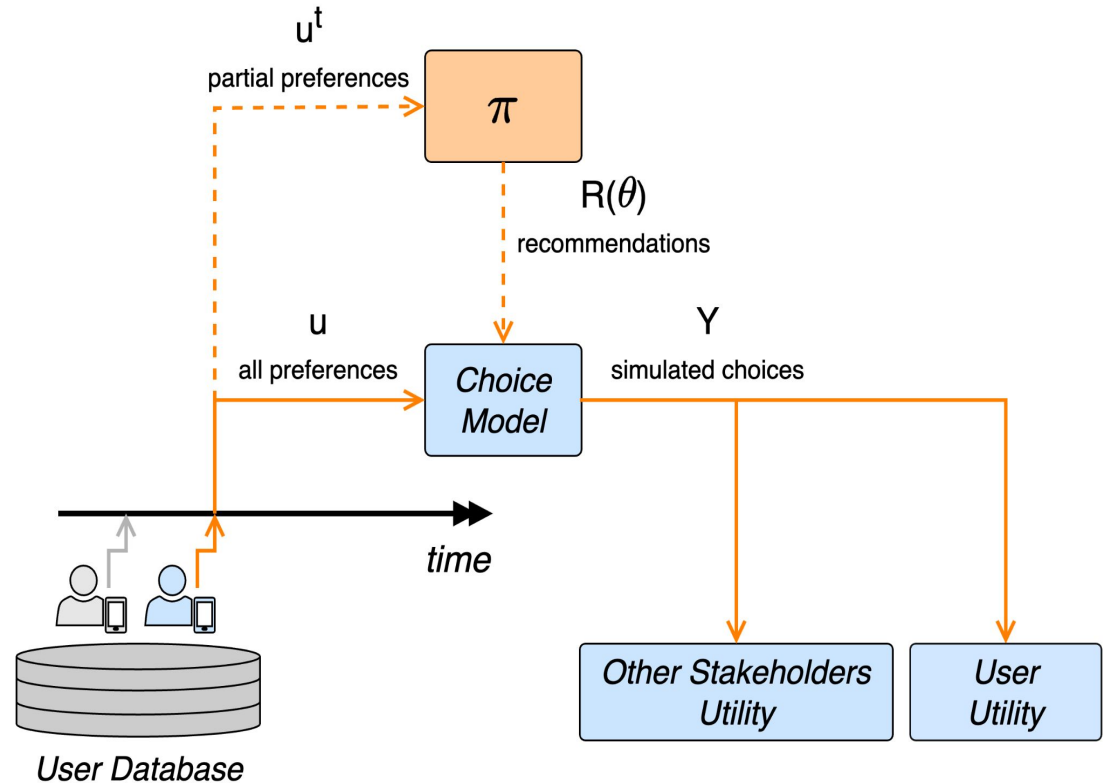
### 3) What Can Be Improved?

#### Users database

- more data

#### Choice/Interaction model

- better user model
- better simulation protocol



## Summary

(where we should go in deep)

# Vision on Sustainable Recommender Systems and how [AI/ML/Math] Helps

- Same problems as in other RS domains
- AI as an oracle and coordinator of the future dynamics

## 1. model users

- preferences & knowledge
- better understand impact of recommendations on choices
- feedback models

## 2. forecast the evolution of a system w/ RS intervention

- more data
- better simulation protocols

## 3. both: algorithmic and GUI modalities are important

- + optimisation/coordination w.r.t. stochastic user behaviour
- + optimisation/coordination w.r.t. UX

# Relevant AI/ML/Math in Use

- Optimisation of resources (energy, logistics, etc.)
  - RL & constraint programming
  - plenty of robust multiple objective approaches
- Simulation of a population of users – influenced by information
  - (causal) behavioural models from economics
  - models to estimate equilibrium (game theory) in dynamic systems
- Simulation of natural phenomena and particles
  - physics-aware congestion & transportation flow models

Takeaway: We should look more closely at what they are doing

# Our (Sustainable) Research Profile

## **[2024] Simulation of recommender systems driven tourism promotion campaigns**

G Pilponyte, D Massimo, F Ricci

Information Technology & Tourism

## **[2023] Choice models and recommender systems effects on users' choices**

N Hazrati, F Ricci

User Modeling and User-Adapted Interaction

## **[2023] Combining reinforcement learning and spatial proximity exploration for new user and new POI recommendations**

D Massimo, F Ricci

Proceedings of the 31st ACM Conference on User Modeling, Adaptation and Personalization

## **[2023] Behaviour-aware tourist profiles data generation**

P Merinov, D Massimo, F Ricci

Proceedings of the 13th Italian Information Retrieval Workshop

## **[2022] Sustainability driven recommender systems**

P Merinov, D Massimo, F Ricci

Proceedings of the 12th Italian Information Retrieval Workshop

## **[2022] Recommender systems effect on the evolution of users' choices distribution**

N Hazrati, F Ricci

Information Processing & Management