Extending Contexts to Multi-Entity Recommender Systems

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RECSYS 2020 at the Workshop on Context-Aware Recommender Systems, Sep 25, 2020

Extending Contexts to Multi-Entity RecSys

- Questions
  - Can we build or utilize CARS in a system which does not have explicit contexts info?
  - Or, are there any connections between CARS and other types of the recommender systems?

Extending Contexts to Multi-Entity RecSys

- Related Issues or Topics
  - Revisit contexts & Context-Aware RecSys (CARS)
  - Utilize CARS without "contexts"?
    - Contextual vs Conditional
    - Case study in Multi-Entity RecSys

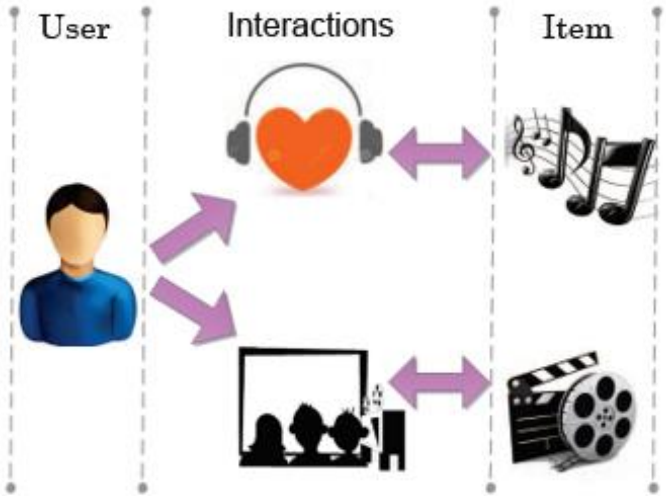
Contexts & CARS: A Revisit

Notion of Contexts

- "Context is any information that can be used to characterize the situation of an entity" by Anind K. Dey, 2001
- In recommender systems
  - Entity: the end user
  - Situation: the interactions between users and the system
    - Listen to a song
    - Watch a movie
    - Shop items on Amazon.com
    - ….

Notion of Contexts

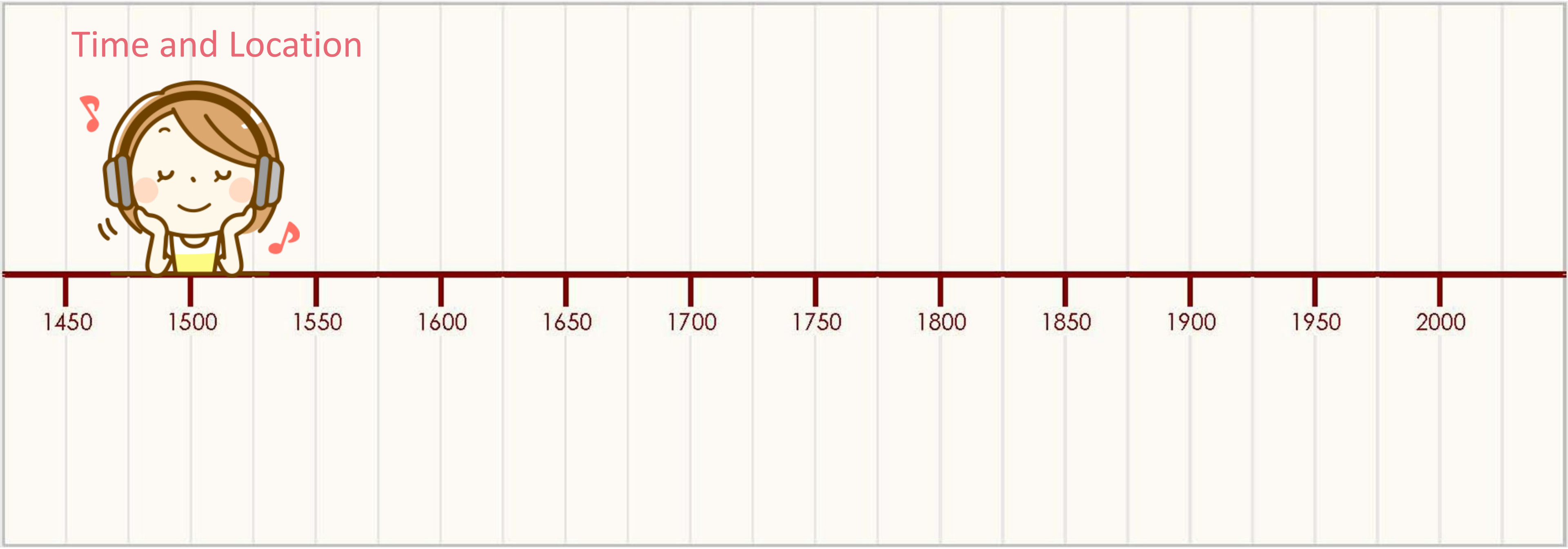
- What are the context variables
  - Attributes of the situation or the interactions
    - Time, location
    - Weather, budget
    - Companion, etc
  - Dynamic attributes of the user
    - Emotion states
    - Objectives or intentions



Everytime when you repeat these interactions or behaviors, the values in these variables may change!

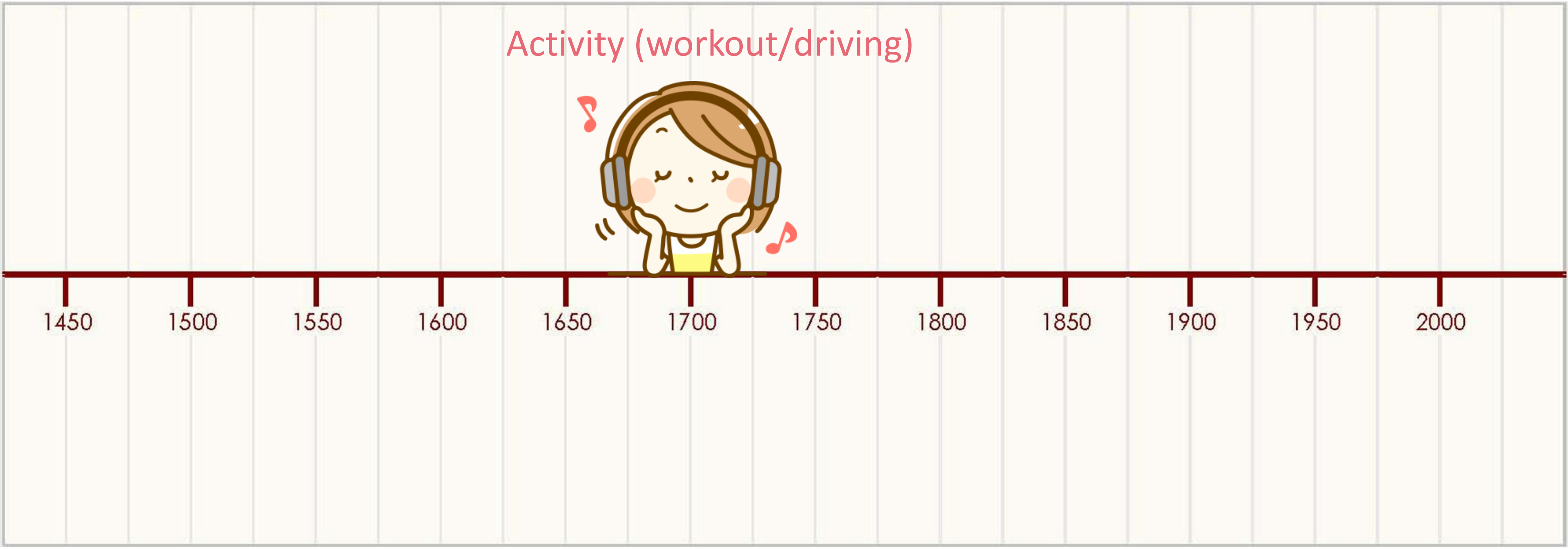
Interactive & Dynamic

- Context and its importance may change



Interactive & Dynamic

- Context and its importance may change



Interactive & Dynamic

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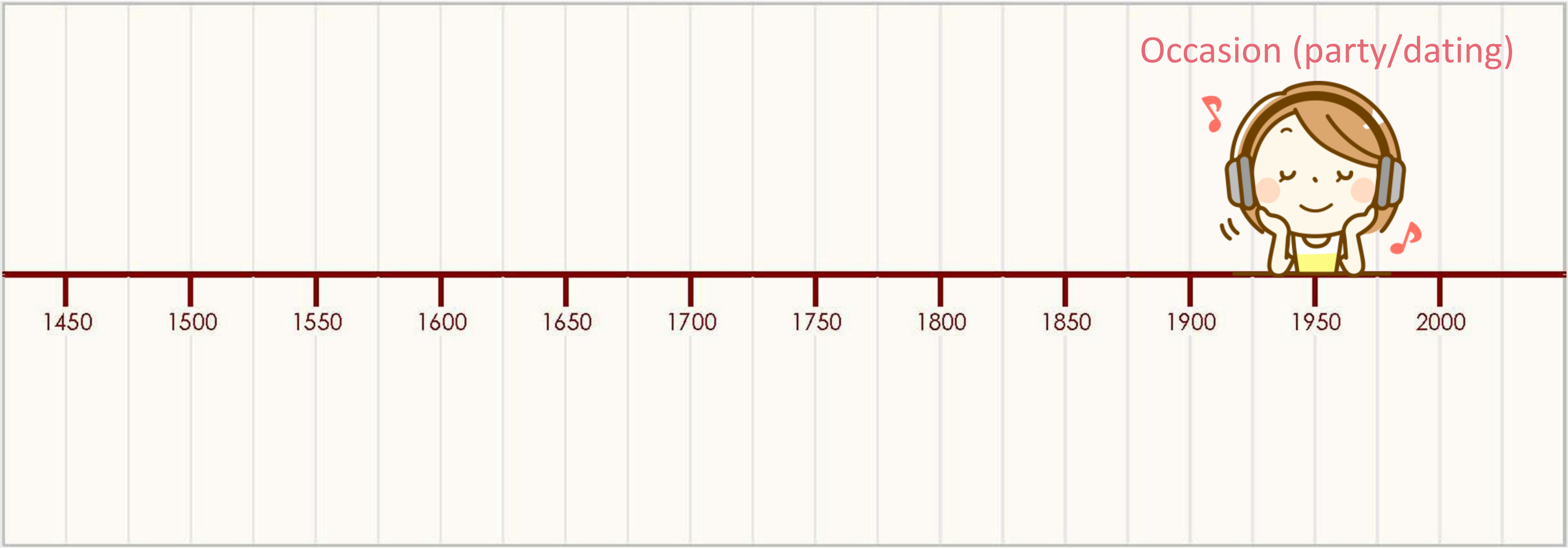


Notion of Contexts

- Gediminas Adomavicius, Bamshad Mobasher, Francesco Ricci, Alexander Tuzhilin. "Context-Aware Recommender Systems", AI Magazine, 2011

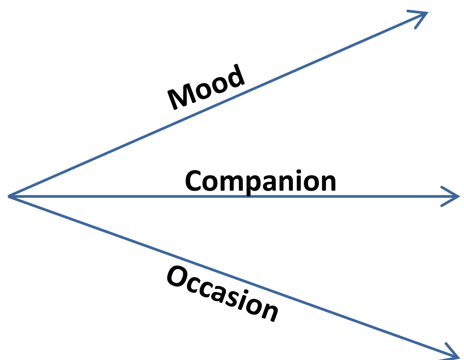
How Contextual Factors Change	Knowledge of the RS about the Contextual Factors		
	Fully Observable	Partially Observable	Unobservable
Static	Everything Known about Context	Partial and Static Context Knowledge	Latent Knowledge of Context
Dynamic	Context Relevance Is Dynamic	Partial and Dynamic Context Knowledge	Nothing Is Known about Context

What is Context-Awareness

- “Context-Awareness” is popular in Ubiquitous computing, such as smart home devices
- Components
  - Sensors
  - Detections
  - Adaptive Actions

Context-Aware Systems

- Context-Aware Systems are adaptive systems
- In context-aware recommender systems
  - Assumption: user preferences or decisions may vary from contexts to contexts



Development of CARS

- Static CARS (patterns may not change frequently)
  - CARSKit library is used in this category https://github.com/irecsys/CARSKit
    - Contexts are fully observed
    - Patterns are fixed
- Interactive CARS
  - Conversational RecSys
  - Session-based RecSys

Contexts: “New” Notion

Build CARS without Explicit Contexts

- I want to build CARS…
  - Do we need to collect contexts?
  - It may be time-consuming & cost-expensive
- Can we extend the notion of contexts?

Contextual vs Conditional

- Contextual Predictions
  - – Predictions by given a set of contexts
- Conditional Predictions
  - – Predictions by assuming some conditions are true

Contextual Recommendations ≈ Conditional Recommendations

Multi-Entity RecSys

Multi-Entity Recommender Systems

- Multi-Entity or Multi-Dimension RecSys are the recommender systems which are built on multi-dimensional data
- More dimensions rather than users & items
- Examples
  - Context-Aware RecSys
  - Multi-Criteria RecSys
  - Tag-based RecSys

Context-Aware Recommender Systems

- Example of the context-aware data set

User	Item	Rating	Time	Location	Companion
U1	T1	3	Weekend	Home	Kids
U1	T2	5	Weekday	Home	Partner
U2	T2	2	Weekend	Cinema	Partner
U2	T3	3	Weekday	Cinema	Family
U1	T3	?	Weekend	Cinema	Kids

Multi-Criteria Recommender Systems

- Additional preferences on aspects of the items

My ratings for this hotel

Value
Rooms
Location
Cleanliness
Check in / front desk
Service
Business service (e.g., internet access)

Date of stay September 2008

Visit was for Other

Traveled with Solo traveler

Age group 35-49

Member since March 05, 2005

Would you recommend this hotel to a friend? Yes

User	Item	Rating	Location	Room Size	Cleanliness
U1	T1	3	3	3	3
U2	T2	5	5	5	5
U3	T2	2	2	3	3
U4	T3	3	3	2	3

Tag-Based Recommender Systems

- Users assign tags on the items
- Explicit ratings are optional

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User	Item	Rating	Tag1	Tag2	Tag3
U1	T1	3	1	0	0
U2	T2	5	1	1	0
U3	T2	2	0	0	1
U4	T3	3	0	1	1

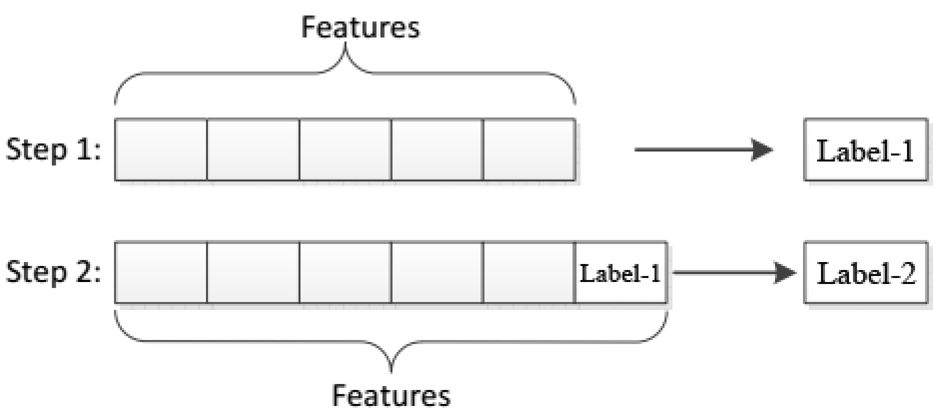
Multi-Entity Recommender Systems

- They have the same characteristics
  - More than two dimensions
  - They are not demographic info or item features
  - Either user interactions or attributes of the interactions
    - CARS: contexts are the attributes of the interactions
    - Multi-Criteria: user ratings on different criteria
    - Tag-based: tag usage

Multi-Entity RecSys with Conditions/Contexts

Multi-Entity Recommender Systems

- Extending Contexts/Conditions to them
  - Chains-Based Methods
    - Read, J., Pfahringer, B., Holmes, G., & Frank, E. (2011). Classifier chains for multi-label classification. Machine learning, 85(3), 333.



- ❑ Define a label sequence
- ❑ Predict labels in queue
- ❑ Previous predictions added as new features for next prediction

Multi-Entity Recommender Systems

- We extend chains to RecSys
  - Multi-Criteria => Criteria Chains
  - Context-Aware => Context Chains
  - Tag-Based RecSys => Tag Chains

Multi-Criteria Recommender Systems

- Criteria Chains
  - Zheng, Yong. "Criteria chains: a novel multi-criteria recommendation approach." In Proceedings of the 22nd International Conference on Intelligent User Interfaces, pp. 29-33. 2017.

  - Given your tastes on different criteria in mind (i.e., conditional process), would you like to finally book this hotel (i.e., final overall rating)?

Multi-Criteria Recommender Systems

- Criteria Chains

Table 1. Example of Rating Data from TripAdvisor

User	Item	Rating	Room	Check-in	Service
U_1	T_1	3	3	4	3
U_2	T_2	4	4	4	5
U_3	T_1	?	?	?	?

Step 1. define the sequence, Room -> Checkin -> Service

Step 2. predict U_3's rating on T_1 in criterion "Room"

[Step 3]. $U_3 + T_1 + Rating_{room} = Rating_{checkin}$

[Step 4]. $U_3 + T_1 + Rating_{room} + Rating_{checkin} = Rating_{service}$

[Step 5]. $U_3 + T_1 + Rating_{room} + Rating_{checkin} + Rating_{service}$ = U_3's predicted overall rating on T_1

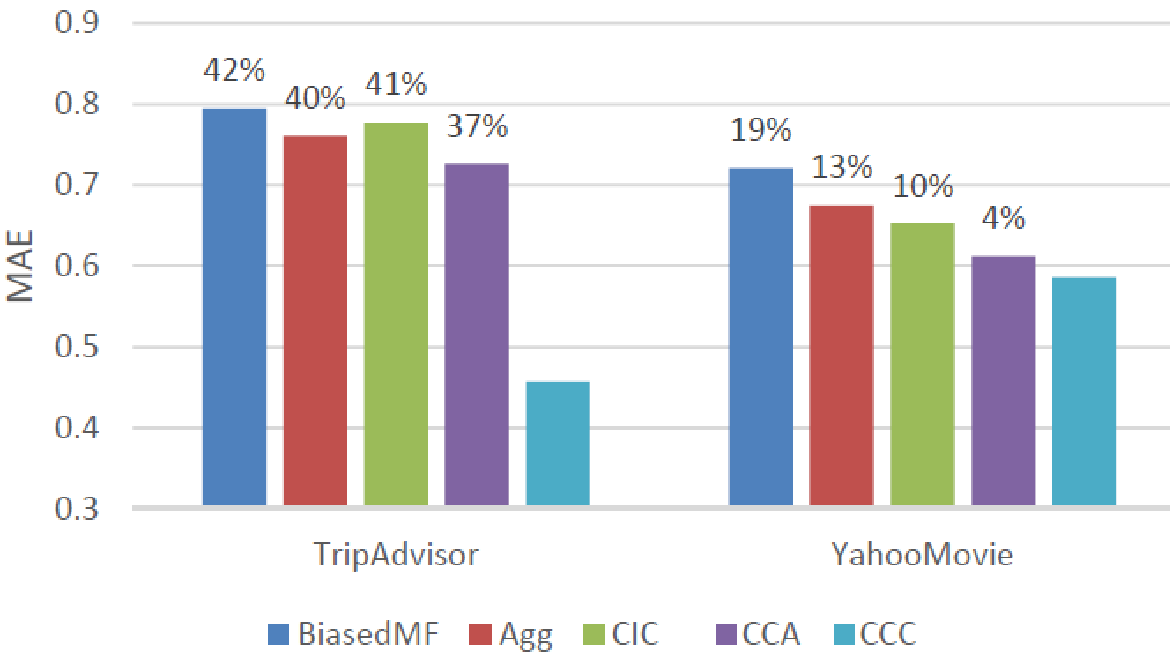
Multi-Criteria Recommender Systems

- Criteria Chains can better predict multi-criteria ratings

Multi-Criteria Recommender Systems

- Criteria Chains can better predict overall ratings

CIC, CCA & CCC are different aggregation methods



Multi-Entity Recommender Systems

- Advantages
  - No more new algorithms
  - Chain method delivers a new pipeline
  - Existing algorithms can be applied
- Challenges & Risks
  - Define the sequence in the chain, i.e., information gain
  - Personalized the sequence for users or user groups
  - Wrong predictions may affect next predictions

Context-Aware Recommender Systems

- Context Chains
  - Zheng, Yong, and Alisha Anna Jose. "Context-aware recommendations via sequential predictions." In Proceedings of the 34th ACM/SIGAPP Symposium on Applied Computing, pp. 2525-2528. 2019.

User	Item	Rating	Time	Location	Companion
U_1	T_1	3	weekend	home	alone
U_1	T_1	5	weekend	cinema	partner
U_1	T_1	?	weekday	home	family

Table 1: Contextual Rating Data

User	Item	Rating	Time	Location	Companion
U_1	T_1	3	weekend:4	home	alone
U_1	T_1	5	weekend:4	cinema	partner
U_1	T_1	?	weekday:3	home	family

Table 2: Example: First-Step Prediction

User	Item	Rating	Time	Location	Companion
U_1	T_1	3	weekend:4	home	alone:3
U_1	T_1	5	weekend:4	cinema	partner:5
U_1	T_1	?	weekday:3	home	family:2

Table 3: Example: Second-Step Prediction

User	Item	Rating	Time	Location	Companion
U_1	T_1	3	weekend:4	home:3	alone:3
U_1	T_1	5	weekend:4	cinema:5	partner:5
U_1	T_1	?	weekday:3	home:3	family:2

Table 4: Example: Third-Step Prediction

  - By this way, we create finer-grained context conditions
  - Convert predicted ratings to binary rates, to reduce sparsity

Context-Aware Recommender Systems

- Context Chains
  - Zheng, Yong, and Alisha Anna Jose. "Context-aware recommendations via sequential predictions." In Proceedings of the 34th ACM/SIGAPP Symposium on Applied Computing, pp. 2525-2528. 2019.

MAE Results

		Food	Restaurant	DePaulMovie	CoMoDa	Frappe
Baselines	MF	0.9234	0.9782	0.7040	0.8215	0.3809
	UISplitting	0.8048	0.8233	0.7130	0.7750	0.3781
	SPF	0.8996	0.8082	0.7220	0.8188	0.3818
	CAMF	0.8461	0.8706	0.6800	***0.6867***	0.3789
	TF	0.9659	0.9537	0.6920	0.8506	0.3921
Context Chains	SeqN	***0.6804*** ○●	***0.7199*** ○●	***0.6236*** ○●	***0.6845*** ○	***0.3532*** ○●
	SeqB	0.6811	0.7225	0.6271	0.6757	0.3525
	Improvement	15.45%	10.93%	8.29%	0.3%	6.77%

Tag-Based Recommender Systems

- Tag Chains (in progress..)
  - Recommend items to a user by given a set of tags

User	Item	Rating	Tag1	Tag2	Tag3
U1	T1	3	1	0	0
U2	T2	5	1	1	0
U3	T2	2	0	0	1

  - Challenge: too may tag dimensions
  - Solution: using tag clusters as dimensions

Summary & Discussions

Contextual vs Conditional

- Contextual Systems
  - Predictions by given a set of contexts
- Conditional Systems
  - Predictions by assuming some conditions are true

Contextual Recommendations ≈ Conditional Recommendations

Summary

- We consider the process of decision making as multiple steps in a chain
- Conditional Predictions
  - Predict outcomes conditional on previous predictions
  - The chain method defines a pipeline
  - No new algorithms were developed
  - Add user preferences to these additional dimensions
  - CARS rating prediction models can be utilized
- Utilize context-aware predictions without explicit contexts information, but in a conditional process

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