E-Commerce Commonsense Knowledge Graphs for Intention-based Recommendation

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KnowComp Group

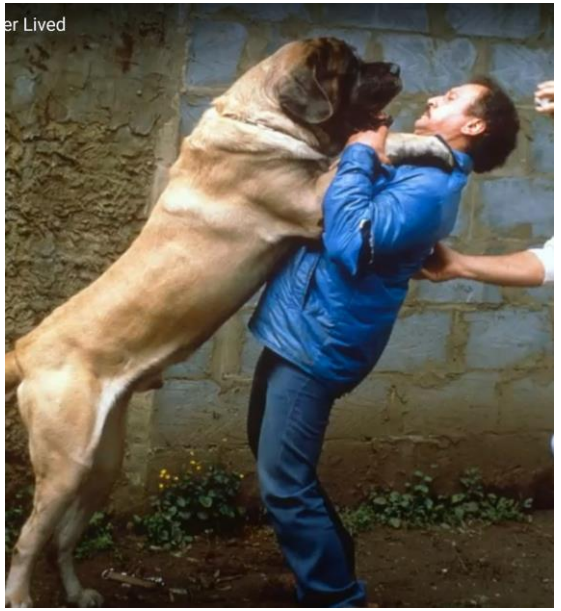
Understanding the World by Computational Knowledge

What is Commonsense (in AI)?

- "Commonsense knowledge includes the basic facts about events (including actions) and their effects, facts about knowledge and how it is obtained, facts about beliefs and desires. It also includes the basic facts about material objects and their properties. " – John McCarthy

- "While to the average person the term 'commonsense' is regarded as synonymous with 'good judgement', the AI community it is used in a technical sense to refer to the millions of basic facts and understandings possessed by most people." --ConceptNet
  - "Such knowledge is typically omitted from social communications", e.g.,
  - If you forget someone's birthday, they may be unhappy with you.

- Meanwhile, it is not invariably true
  - "a person is larger than a dog"



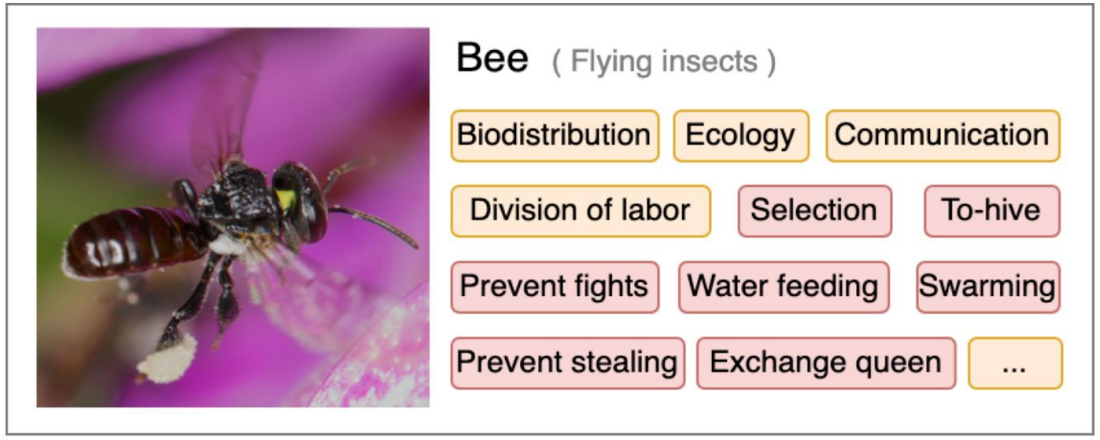
Source: Zorba - The World's Largest Dog Ever Lived

McCarthy, John. "Artificial intelligence, logic and formalizing common sense." Philosophical logic and artificial intelligence. Springer, Dordrecht, 1989. 161-190.
H Liu and P Singh, ConceptNet - a practical commonsense reasoning tool-kit, BTTJ, 2004

What is Commonsense (in AI)?

- Such kind of knowledge exist in many
  - Cause-effect inferences
  - If-then conditions
  - Making sense of actions
    - Event-state interactions
- And different types of knowledge
  - Knowledge-that
    - Factual knowledge
  - Knowledge-why and knowledge-how
    - Practical knowledge, ability knowledge, etc.

"I think, therefore I am"
-- the "first principle" of
René Descartes's philosophy



The aspects in orange boxes are aspects that convey the knowledge of “know-what” or “know-why”, while those in red boxes convey the knowledge of “know-how”.

Source: Kuaipedia

https://en.wikipedia.org/wiki/Definitions_of_knowledge#Non-propositional_knowledge

Kuaipedia: a Large-scale Multi-modal Short-video Encyclopedia Haojie Pan, Zepeng Zhai, Yuzhou Zhang, Ruiji Fu, Ming Liu, Yangqiu Song, Zhongyuan Wang, Bing Qin. Arxiv 2022.

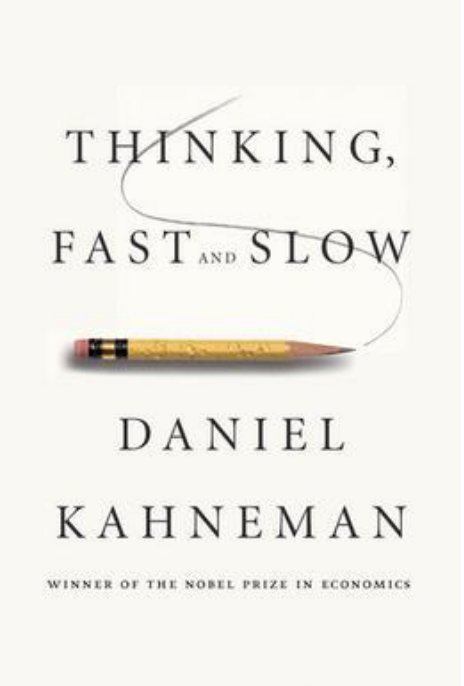
Why Is It So Difficult to Understand by Machines?

KnowComp
Understanding the World by Computational Knowledge

"If you forget someone's birthday, they may be unhappy with you." Inference involves:

- 1. System II Processing
  - We need to equip machine learning systems with "slow, logical, sequential, conscious, linguistic, algorithmic, planning, reasoning"

- Particularly, such a system requires the "understanding of how actions interact with changes (of states) in distribution"
  - "Agents face non-stationarities"
  - Conditioned on "different places, times, sensors, actuators, goals, policies, etc"



http://www.iro.umontreal.ca/~bengioy/AAAI-9feb2020.pdf

Why Is It So Difficult to Understand by Machines?

"If you forget someone's birthday, they may be unhappy with you." Inference involves:

- 2. Theory of Mind
  - i.e., the development of knowledge that others have beliefs, desires, and intentions that are different from one's own
  - Possessing a functional theory of mind is crucial for success in everyday human social interactions

- What makes us take actions?
  - Beliefs and desires are mediated by intentions which in turn controls human's actions (or speech) (Kashima et al., 1998)
  - Intentions are implicit

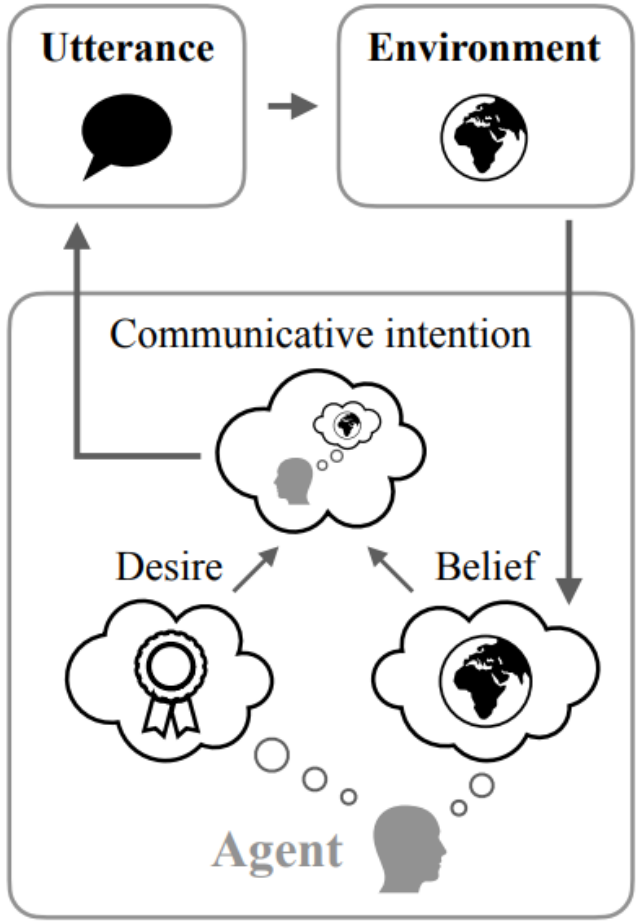


Figure taken from Andreas (2022)

https://en.wikipedia.org/wiki/Intention
https://en.wikipedia.org/wiki/Theory_of_mind

Jacob Andreas: Language Models as Agent Models. EMNLP (Findings) 2022: 5769-5779
Kashima, Yoshihisa, Allison McKintyre, and Paul Clifford. "The Category of the Mind: Folk Psychology of Belief, Desire, and Intention." Asian Journal Of Social Psychology 1, no. 3 (December 1998): 289–313.

Commonsense Knowledge about Intentions

- We define the commonsense knowledge about intention to be
  - Common/collective: collective basic rationales of actions possessed by most people
  - Implicit: some mental states before taking actions
    - Cannot be extracted from texts, e.g., reviews
  - Aligned with knowledge defined in ConceptNet: Things, Spatial, Location, Events, Causal, Affective, Functional, Agents, …
  - Natural language-based knowledge representation:
    - Similar to ConceptNet
    - More meaningful nodes and edges
    - Aligned with K-Lines (Minsky, 1980), a primary mechanism for context and memory

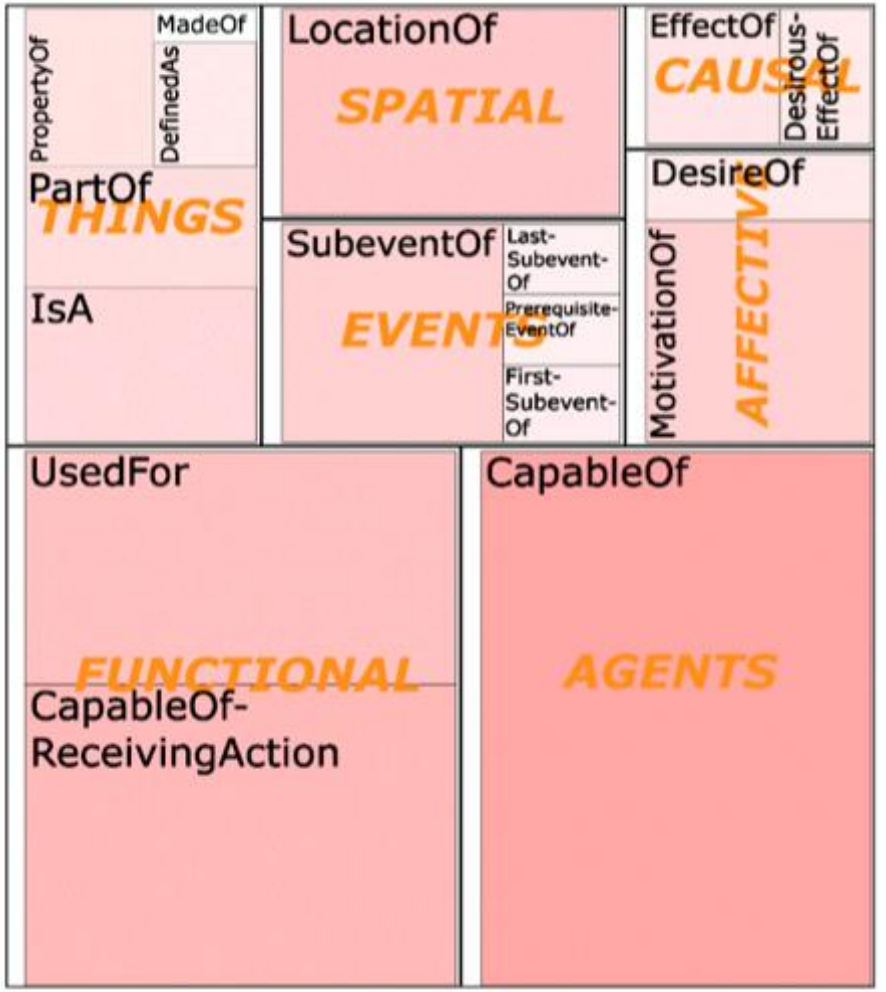
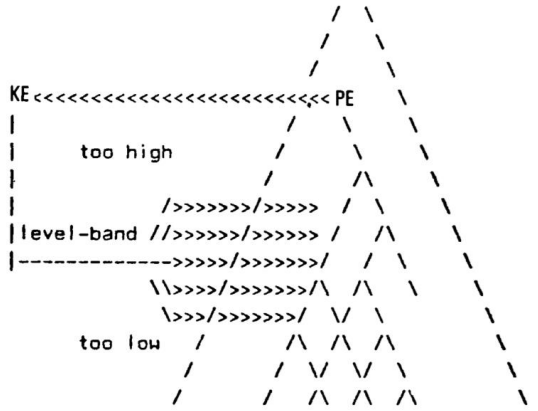


Figure taken from Liu and Singh (2004)

H Liu and P Singh, ConceptNet - a practical commonsense reasoning tool-kit, BTTJ, 2004
M. Minsky, “K-Lines: A theory of Memory," Cognitive Science 4 (1980). 117-133.

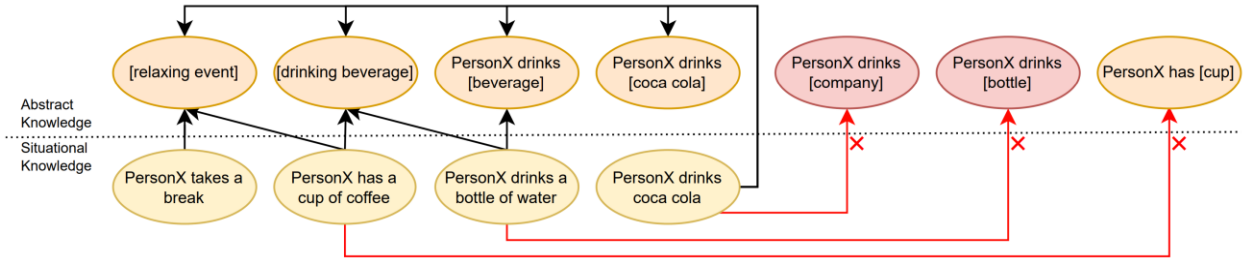
Why Graphs?



K-Pyramid: Minsky (1980)

- The K-Line Theory (Minsky, 1980)
  - More than ontology: categories include substances, properties, relations, states of affairs, and events
  - Mental states in our memory are also in a hierarchical structure beyond an ontology; described as a K-pyramid

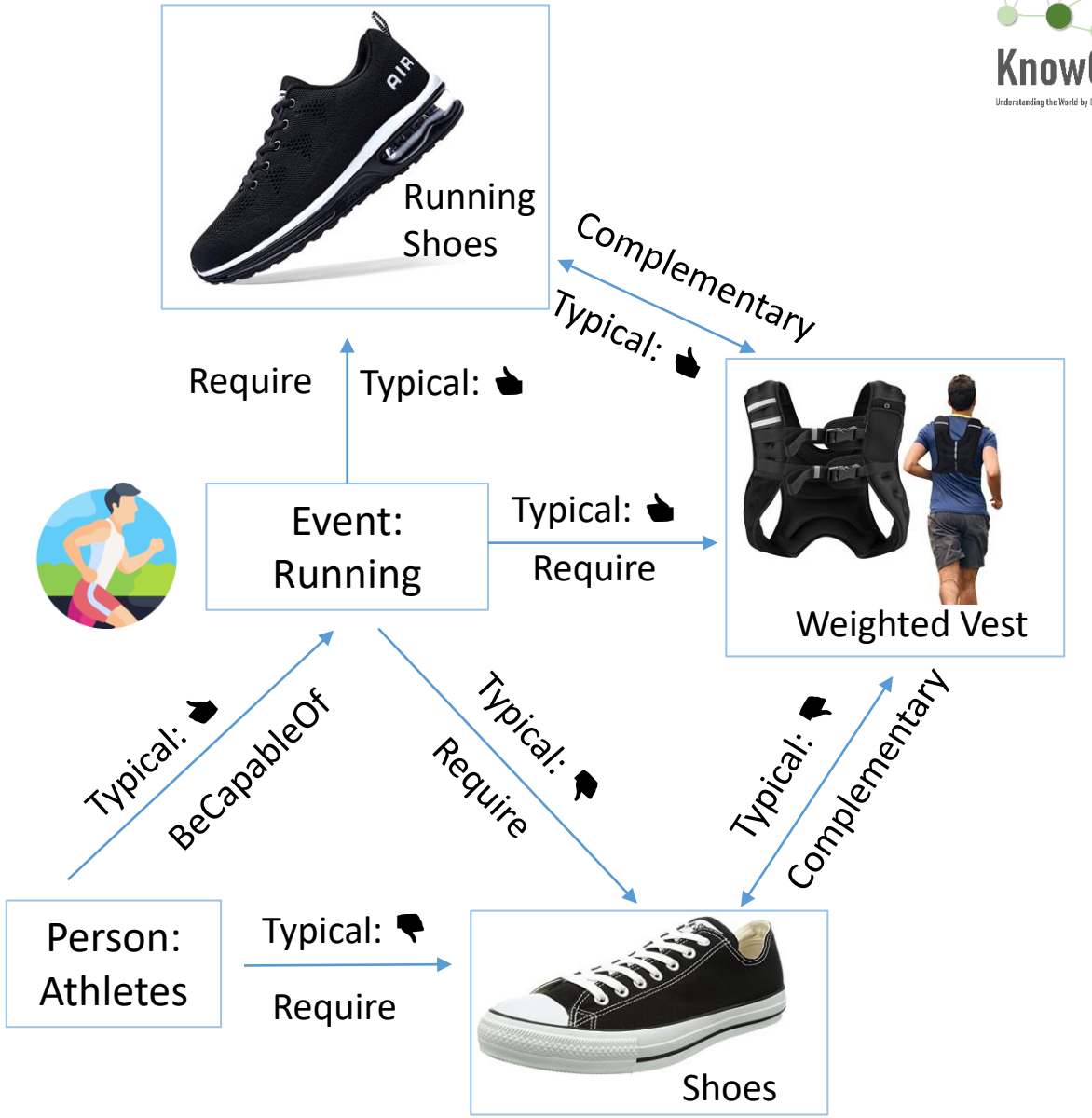
- We need the right level and right perspective of abstraction
  - Different levels of abstractness
    - "PersonX drinks coca cola" → "[drinking beverage]," "[event]"
  - Different perspectives
    - "Coca cola" → "[sugary beverage]," "[phosphate containing beverage]," "[iced drink]," not in a strict taxonomy
      - PersonX drinks [iced drink], xReact, refreshed
      - PersonX drinks [sugary beverage], xEffect, gain weight



M. Minsky, "K-Lines: A theory of Memory," Cognitive Science 4 (1980). 117-133.
Mutian He, Tianqing Fang, Weiqi Wang, and Yangqiu Song. Acquiring and Modelling Abstract Commonsense Knowledge via Conceptualization. Arxiv 2022.

Why Graphs?

- Sometimes we need concrete, symbolic, and globally referenced knowledge
- Ability of commonsense reasoning with high complexity
  - NP-complete problems, e.g., Max-Sat (Chalier et al., 2022) , subgraph matching or counting, subset sum, etc.
- The trade-offs between scalability and computational complexity
  - Intentions can be pre-stored and indexed to be more efficiently accessed online



Joint Reasoning for Multi-Faceted Commonsense Knowledge. Yohan Chalier, Simon Razniewski, Gerhard Weikum. ACBC. 2022.

The Agent Model in E-commerce

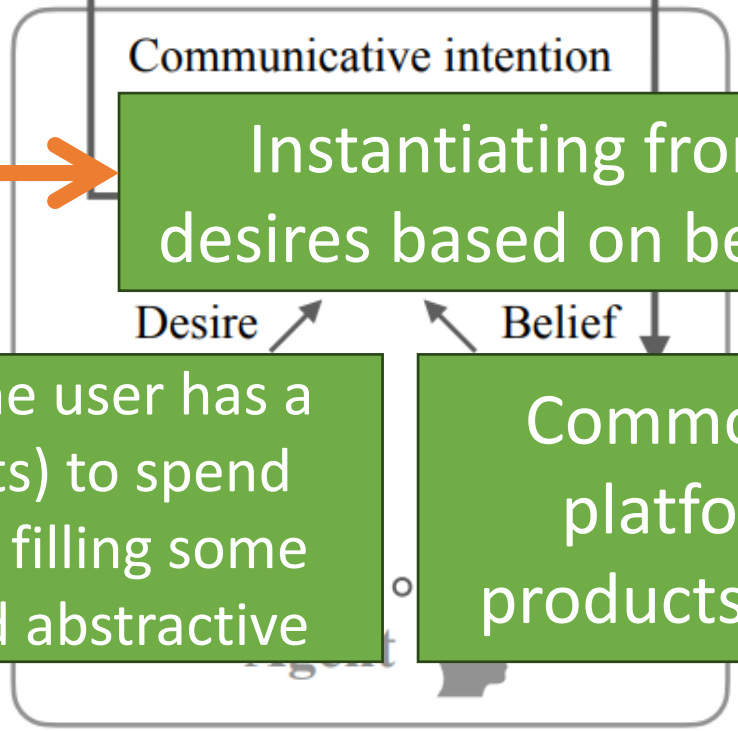
Actions on the platform: search, browse, purchase, etc.

E-commerce platform

An Intention KG can equip the platform for better alignment

Crucial to understand the actions and desires of users

Traditional Product KGs



A state of mind whereby the user has a personal motivation (wants) to spend money and buy something filling some needs: more high-level and abstractive

Common ground of users and the platform: knowledge about the products, e.g., attributes, prices, etc.

Figure taken from Andreas (2022)

Jacob Andreas: Language Models as Agent Models. EMNLP (Findings) 2022: 5769-5779
Perugini, Marco and Richard P. Bagozzi. "The distinction between desires and intentions." European Journal of Social Psychology 34 (2004): 69-84.

“Language Models as Agent Models”

- “Current LMs sometimes infer approximate, partial representations of the beliefs, desires and intentions possessed by the agent that produced the context”

Pat watches a demonstration of a bowling ball and a leaf being dropped at the same time in a vacuum chamber. Pat, who is a physicist, predicts that the bowling ball and the leaf will fall at the same rate.

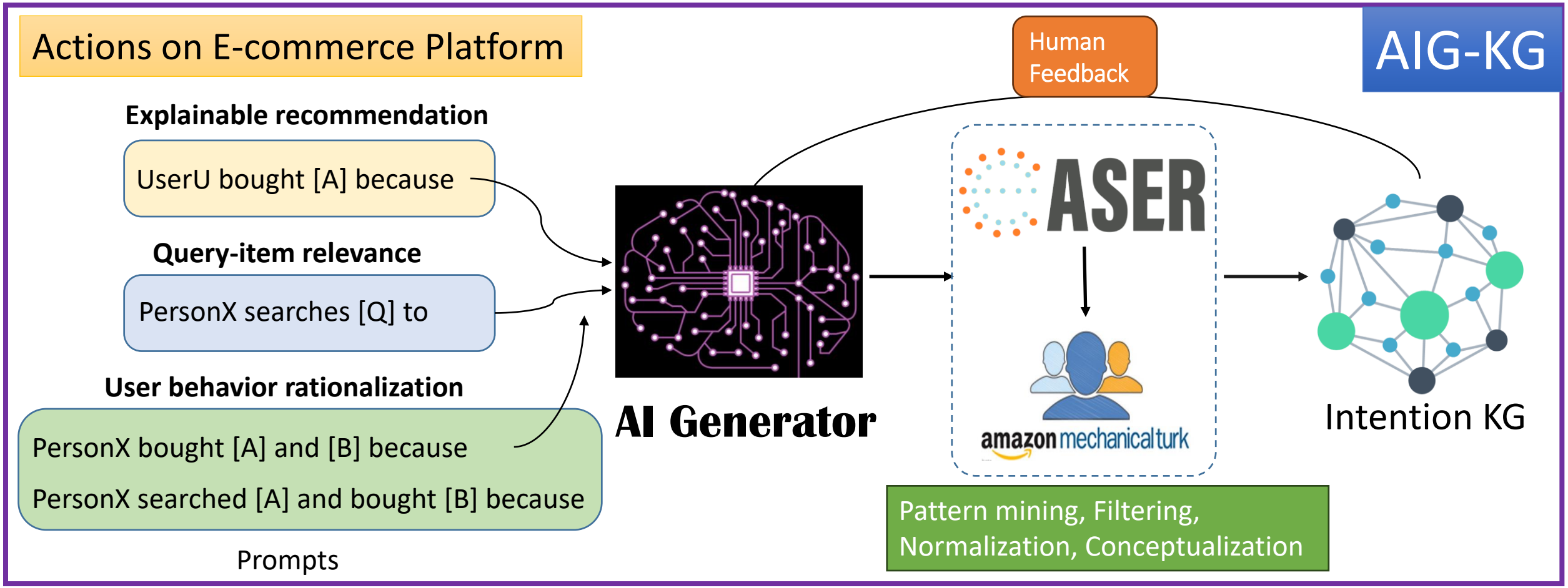
. . . Pat, who has never seen this demonstration before, predicts that the bowling ball will fall to the ground first. This is incorrect. In a vacuum chamber, there is no air resistance. Therefore, both the bowling ball and the leaf will fall at the same rate.

The beliefs of Pat has been told in prompts, so the communicative intent of the language model agent has been changed.

Jacob Andreas: Language Models as Agent Models. EMNLP (Findings) 2022: 5769-5779

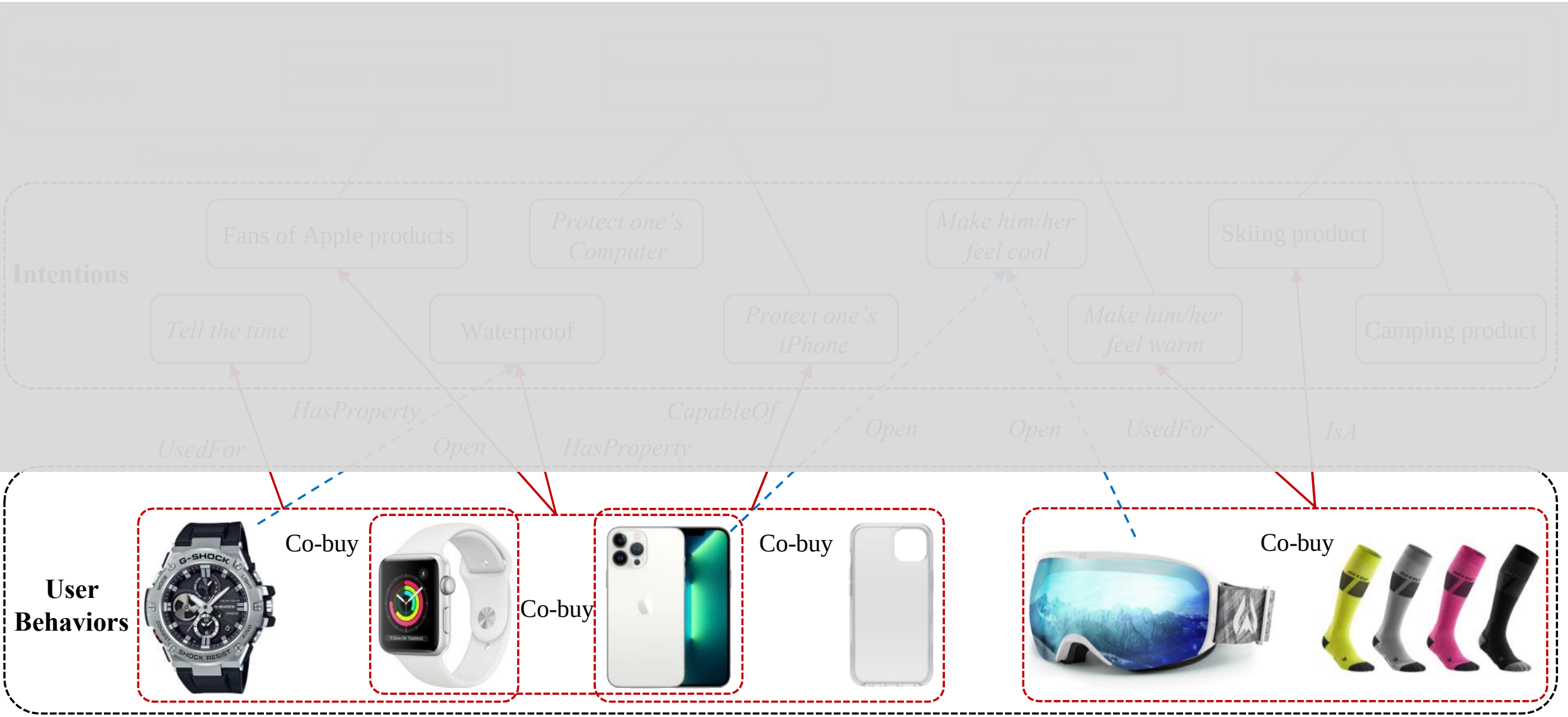
FolkScope and COSMO: Collective Intention KGs

- AI generated knowledge graph construction framework



Changlong Yu, Weiqi Wang, Xin Liu, Jiaxin Bai, Yangqiu Song, Zheng Li, Yifan Gao, Tianyu Cao, and Bing Yin. FolkScope: Intention Knowledge Graph Construction for E-commerce Commonsense Discovery. Findings of ACL. 2023.
Hongming Zhang*, Xin Liu*, Haojie Pan*, Haowen Ke, Jiefu Ou, Tianqing Fang, and Yangqiu Song. ASER: Towards Large-scale Commonsense Knowledge Acquisition via Higher-order Selectional Preference over Eventualities. Artificial Intelligence, Volume 309, August 2022, 103740.

FolkScope: Collective Intention KG for Co-Purchases



COSMO: Collective Intention KG for Search-Buys

E-commerce Commonsense Extraction

User Behaviors

item-item ***co-purchase***

query-item ***search-buy***

Domains

Clothing, Shoes & Jewelry
Sports & Outdoors
Home & Kitchen
Patio, Lawn & Garden
Tools & Home Improvement
Musical Instruments
…

18 Domains

Tasks

5 Tasks

Commonsense Generation
Plausibility Prediction
Typicality Prediction
Search Relevance Prediction
Co-purchase Prediction

Relations

Is_A
Capable_Of
Used_For_Function
Used_For_Event
Used_For_Audience
Used_To
Used_As
Used_On (Time/Season/Event)
Used_in_Location
Used_In_Body
Used_With
Used_By
xInterested_in
xIs_A
xWant

15 Relations

Some Statistics in our Experiments

KG	#Nodes	#Edges	#Rels.	Source	Node Type	E-commerce	Intention	User Behavior
ConceptNet	8M	21M	36	Crowdsource	concept	✗	✓	✗
ATOMIC	300K	870K	9	Crowdsource	daily situation, event	✗	✓	✗
AliCoCo	163K	813K	91	Extraction	concept	✓	✗	search logs
AliCG	5M	13.5M	1	Extraction	concept, entity	✗	✗	search logs
FolkScope	1.2M	12M	19	LLM Generation	product, intention	2 domains	✓	co-buy
COSMO	6.3M	29M	15	LLM Generation	product, query, intention	18 domains	✓	co-buy &search-buy

We spent tens of thousands of US dollars both at HKUST and Amazon for data annotation

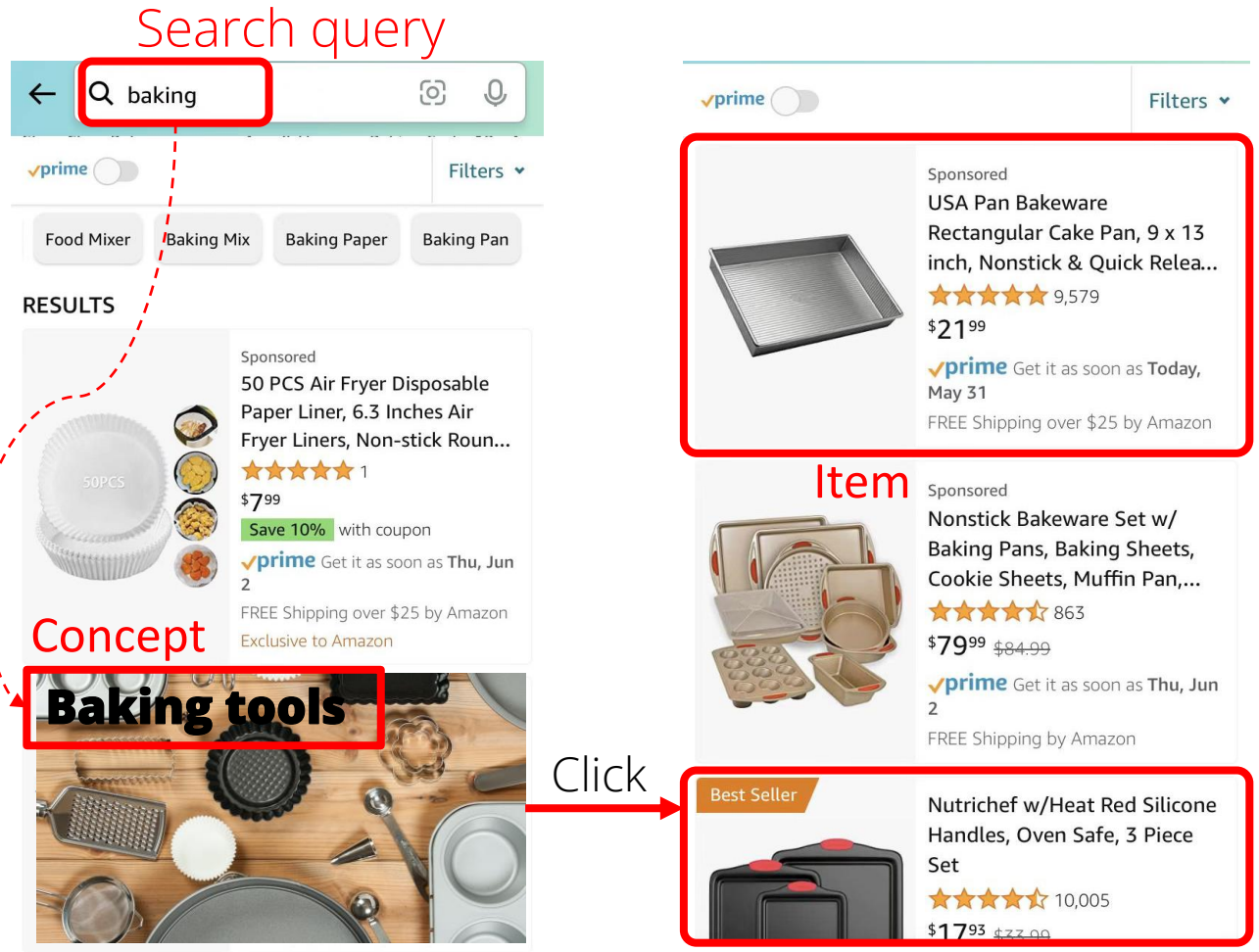
COSMO: A large-scale e-commerce common sense knowledge generation and serving system at Amazon. By Changlong Yu, Xin Liu, Jefferson Maia, Tianyu Cao, Laurence (Yang) Li, Yifan Gao, Yangqiu Song, Rahul Goutam, Haiyang Zhang, Bing Yin, Zheng Li. SIGMOD Industrial Track. 2024.

Deployments

- Efficient feature store and asynchronous cache store
- Effectively meets Amazon's restricted search latency requirements while maintaining storage costs comparable to real-time serving for the majority of traffic

Search Query Navigation

"This conclusion is drawn from meticulously conducted Amazon online A/B tests carried out over several months in total, targeting approximately 10% of Amazon's U.S. traffic. These well-structured tests revealed a notable 0.7% relative increase in product sales within this segment, translating to hundreds of millions of dollars in annual revenue surge."



COSMO: A large-scale e-commerce common sense knowledge generation and serving system at Amazon. By Changlong Yu, Xin Liu, Jefferson Maia, Tianyu Cao, Laurence (Yang) Li, Yifan Gao, Yangqiu Song, Rahul Goutam, Haiyang Zhang, Bing Yin, Zheng Li. SIGMOD Industrial Track. 2024.

Conclusions

- We developed the AIG-KG framework for collective, implicit, free-text-based situational commonsense knowledge extraction for e-commerce intention understanding
  - Globally connected
  - Symbolically executable: efficient and effective
- Many applications in e-commerce including
  - Instruction-tuned COSMO Language Model
  - Search Relevance
  - Session-based Recommendation
  - Search Navigation
  - …
- Real-world deployment
  - Earning hundreds of millions of revenue gain in 2023

Thank you for your attention! ☺