

E-Commerce Commonsense Knowledge Graphs for Intention-based Recommendation

Yangqiu Song

Department of CSE, HKUST

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

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



Bee (Flying insects)

Biodistribution	Ecology	Communication
Division of labor	Selection	To-hive
Prevent fights	Water feeding	Swarming
Prevent stealing	Exchange queen	...

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”.

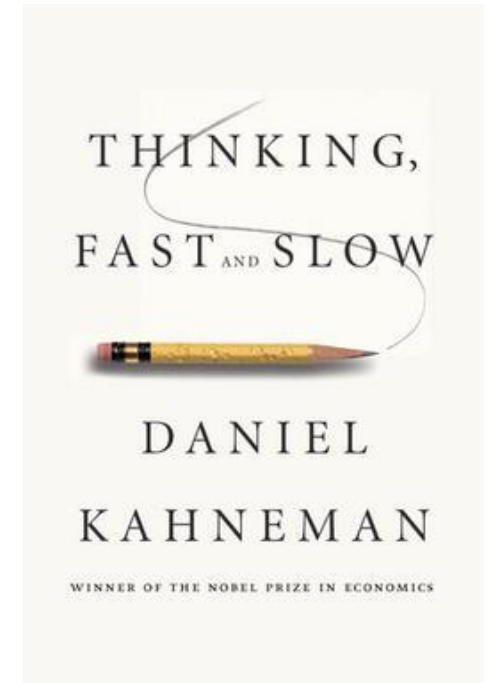
Source: Kuaipedia

Why Is It So Difficult to Understand by Machines?

“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”



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

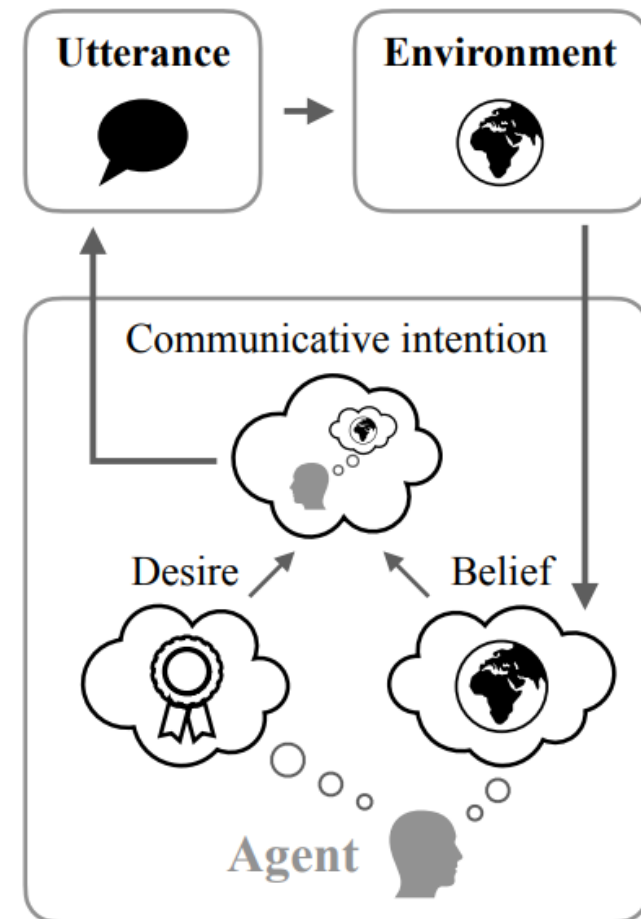


Figure taken from
Andreas (2022)

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

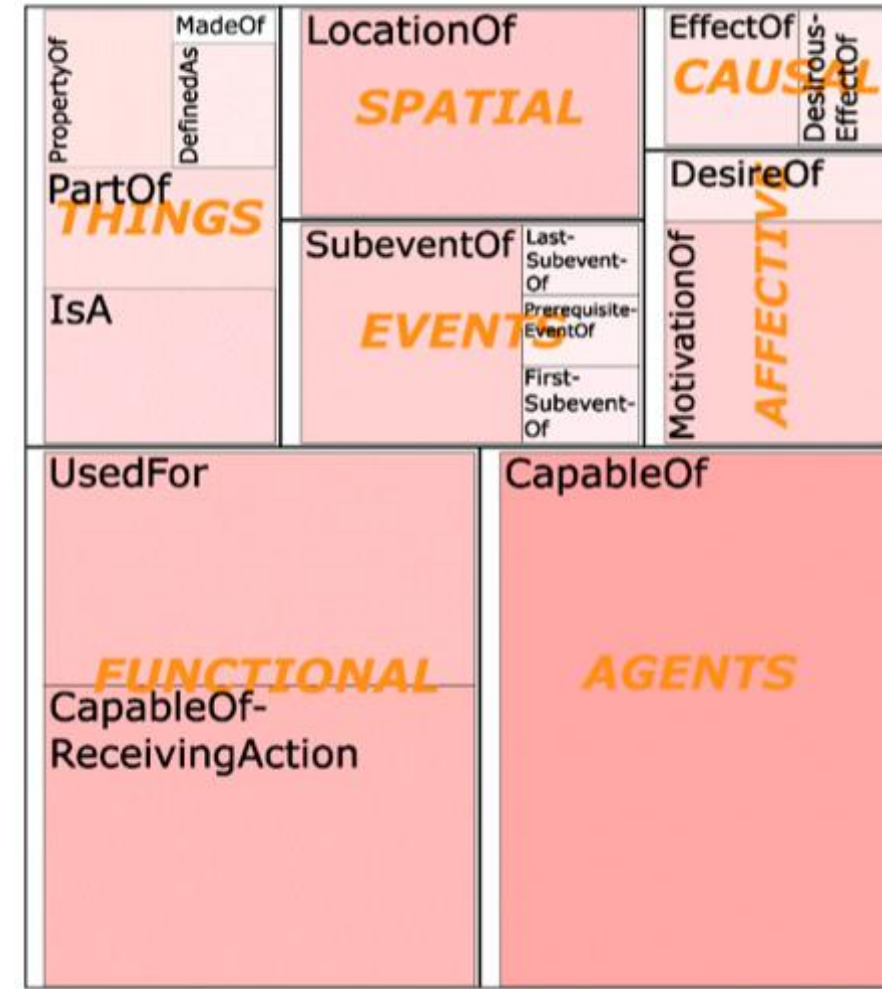
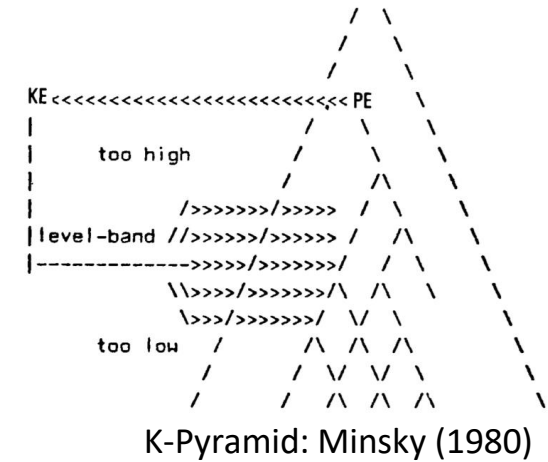


Figure taken from Liu and Singh (2004)

Why Graphs?

- 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**



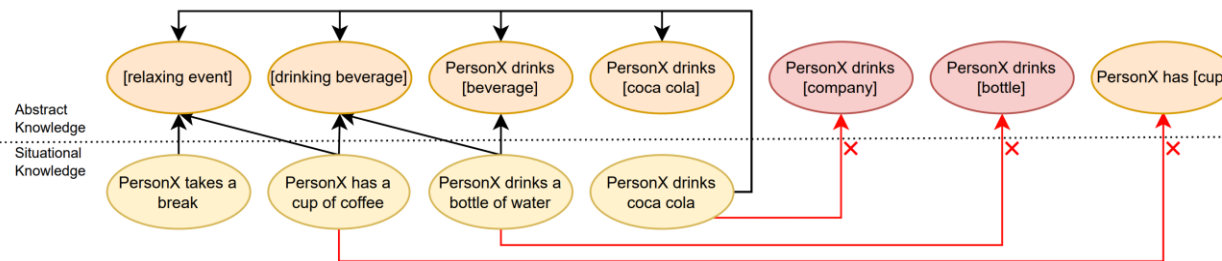
- We need the **right level** and **right perspective** of abstraction

- Different levels of abstractness

- “PersonX drinks coca cola” → “[drinking beverage],” “[event]”

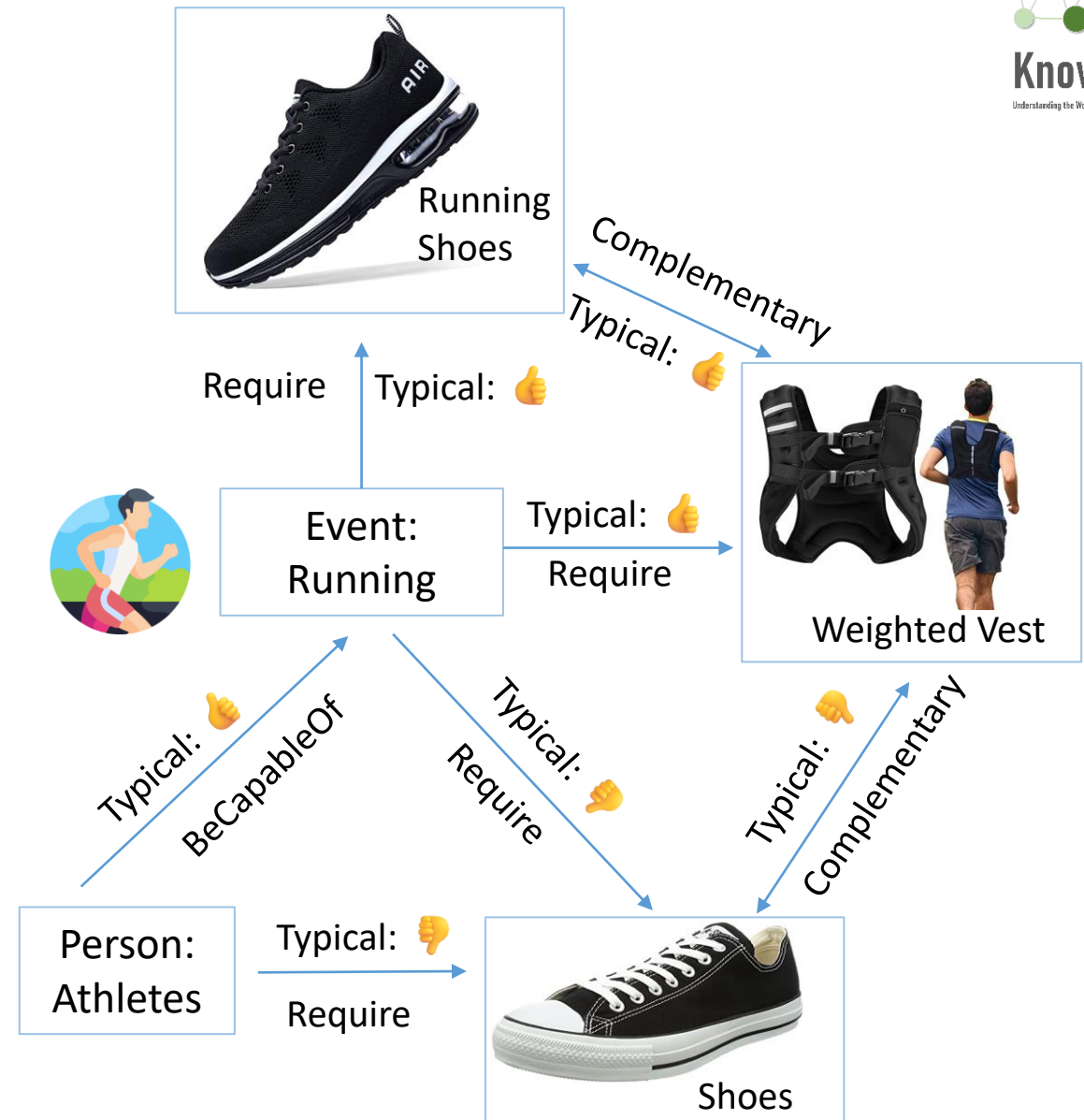
- Different perspectives

- “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



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



The Agent Model in E-commerce

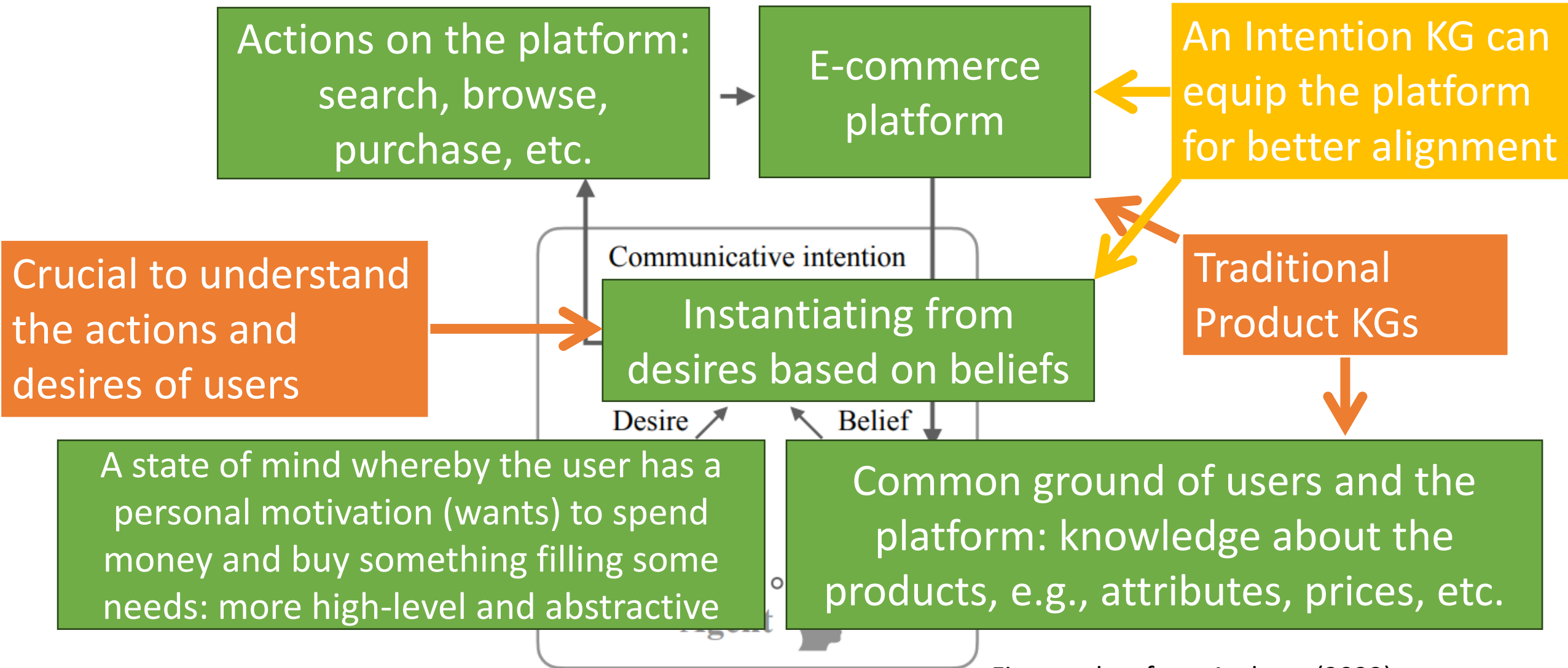


Figure taken from Andreas (2022)

“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”

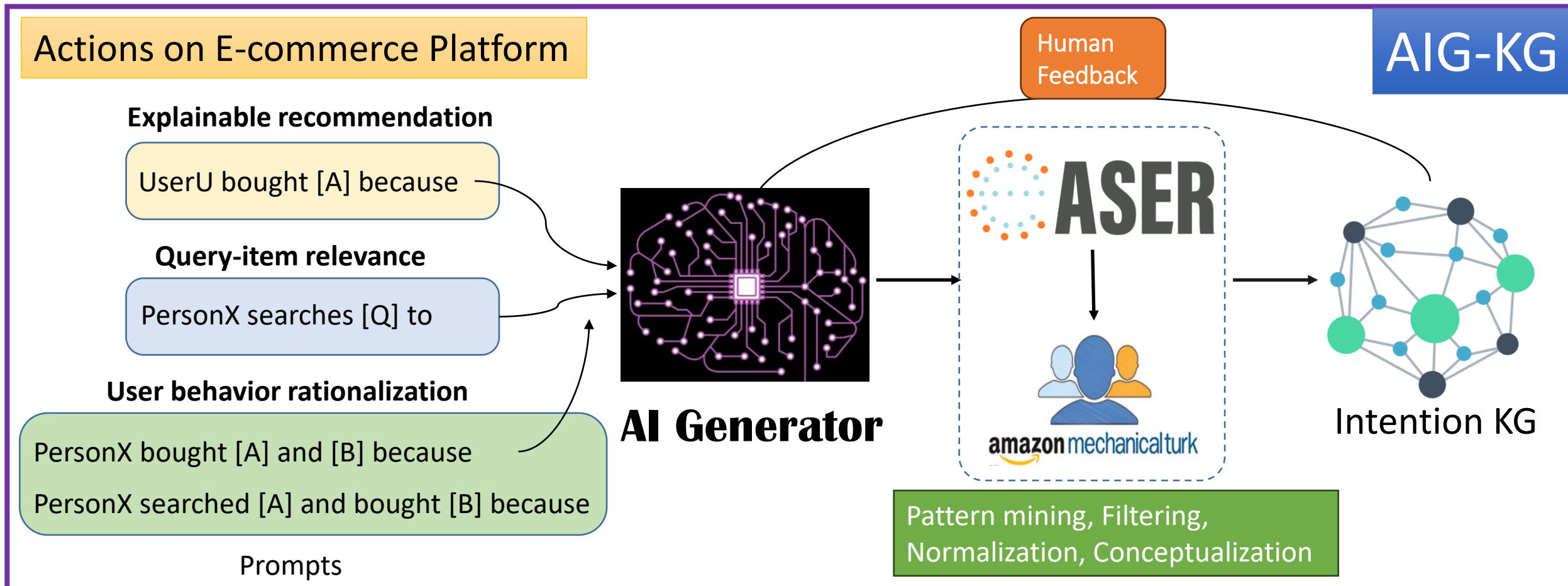
Pat watches a demonstration of a bowling ball and a leaf being dropped at the same time in a vacuum chamber. Pat, who is a physicist, predicts that the bowling ball and the leaf will fall at the same rate.

... 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.

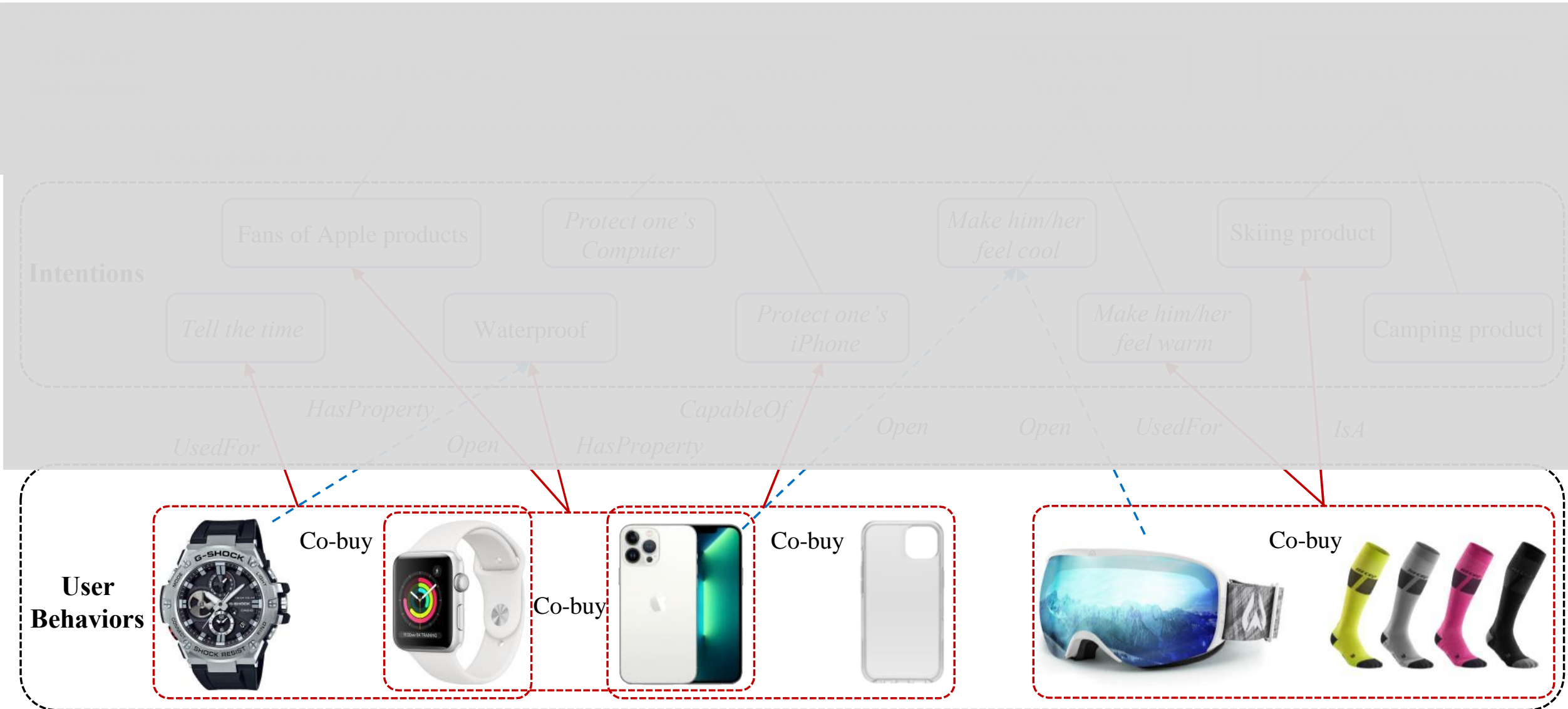
The beliefs of Pat has been told in prompts, so the communicative intent of the language model agent has been changed.

FolkScope and COSMO: Collective Intention KGs

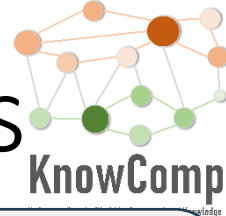
- AI generated knowledge graph construction framework



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	Crowdsourcing	concept	X	✓	X
ATOMIC	300K	870K	9	Crowdsourcing	daily situation, event	X	✓	X
AliCoCo	163K	813K	91	Extraction	concept	✓	X	search logs
AliCG	5M	13.5M	1	Extraction	concept, entity	X	X	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

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**.”

The screenshot shows an Amazon search for 'baking'. A red box highlights the search query 'baking' in the search bar, with a red arrow pointing to the word 'Baking tools' in a red box on a product image below. Another red box highlights a product listing for 'USA Pan Bakeware Rectangular Cake Pan, 9 x 13 inch, Nonstick & Quick Relea...'. A red arrow labeled 'Click' points from the product image to a 'Best Seller' product listing for 'Nutrichef w/Heat Red Silicone Handles, Oven Safe, 3 Piece Set'.

The screenshot shows a social media post by Zheng Li, Senior Applied Scientist@Amazon Search (A9) | NLP Ph.D | Building LLM for shopping. The post discusses the COSMO KG (paper: <https://lnkd.in/g/ghbusFbQ>), the first time accepted to SIGMOD, the top-tier database conference (I'm a NLPer). The post mentions working with two interns Chanlong and Xin together for researching generative knowledge graph construction - using LLM for generating e-commerce knowledge graph COSMO. The post also mentions a recent launch of an AI shopping assistant Rufus. The post includes a screenshot of a search for 'camping essentials' with a red box highlighting the 'COSMO' search results. The post ends with a list of team members: Changlong Y. Xin Liu Yang (Laurence) Li Tianyu Cao Yifan Gao Yangqiu Song Rahul Goutam Haiyang Zhang Bing Yin.

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! 😊