

# Applications

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Overview and Introduction

Knowledge Extraction

Knowledge Cleaning

Q&A

Break

Ontology Mining

**Applications**

20 min



Conclusion and Future Directions

Q&A

# Product Knowledge Graph Applications

- Product knowledge graphs can have a plethora of applications in areas including:
  - Recommendation systems.
  - Search and question answering.
  - Product info and product comparison.
  - Among others.
- Applications can make use of knowledge graphs through:
  - The structured factual information for each product.
  - The connections in the overall graph structure.

# Making Use of Structured Information



Pro Air Fryer 5.8QT



Pro II Air Fryer 5.8QT



WIFI Air Fryer Oven 7QT



Stainless Air Fryer 5.8QT

<b>Included</b>	100 Recipes	100 Recipes	30 Recipes&More Online Recipes	100 Recipes & Rack & 5 Skewers
<b>Control</b>	Digital	Digital	Digital/WIFI	Digital
<b>Capacity</b>	5.8QT	5.8QT	7QT	5.8QT
<b>Color</b>	Black/Red/White	Black	Black	Silver
<b>Cooking Functions</b>	13	12 (Customizable)	14	10
<b>Shake Remind</b>	✓	Customizable Shake Remind	✓	Customizable Shake Remind
<b>Keep Warm</b>	✓	✓	✓	-
<b>Preheat</b>	✓	✓	✓	✓
<b>Power</b>	1700W	1700W	1800W	1700W
<b>Voltage</b>	AC 120V	AC 120V	AC 120V	AC 120V

Facilitating structured product comparison

# Making Use of Structured Information



Roll over image to zoom in

## CeraVe Daily Moisturizing Lotion for Dry Skin | Body Lotion & Facial Moisturizer with Hyaluronic Acid and Ceramides | Fragrance Free | 19 Ounce

[Visit the CeraVe Store](#)

★★★★★ 55,480 ratings | 321 answered questions

**Amazon's Choice** in Body Lotions by CeraVe

Price: **\$18.40** (\$0.97 / Fl Oz) Get **Fast, Free Shipping** with Amazon Prime & **FREE Returns**

Get \$50 off instantly: Pay \$0.00 ~~\$18.40~~ upon approval for the Amazon Rewards Visa Card. No annual fee.

Size: **19 Fl Oz (Pack of 1)**

12 Fl Oz (Pack of 1)  
\$11.49  
(\$0.96 / Fl Oz)

**19 Fl Oz (Pack of 1)**  
**\$18.40**  
**(\$0.97 / Fl Oz)**

<b>Special Ingredients</b>	Hyaluronic Acid
<b>Item Form</b>	Lotion
<b>Brand</b>	CeraVe
<b>Skin Type</b>	Dry
<b>Age Range (Description)</b>	Adult

Conveying structured product details and highlights

# Making Use of Structured Information



Roll over image to zoom in

## Taylors of Harrogate English Breakfast, 20 Count (Pack of 6)

Visit the Taylors of Harrogate Store

★★★★★ 27,415 ratings | 161 answered questions

Climate Pledge Friendly

#1 Best Seller in Tea Samplers

Price: **\$31.43** (\$0.26 / Count)

Get \$50 off instantly: Pay \$0.00 \$31.43 upon approval for the Amazon Rewards Visa Card. No annual fee.

Available at a lower price from other sellers that may not offer free Prime shipping.

Style: **Teabags**



Flavor Name:

English Breakfast ▾

Size: **20 Count (Pack of 6)**

20 Count (Pack of 1)

**20 Count (Pack of 6)**

48 Count (Pack of 1)

100 Count (Pack of 1)

Brand	Taylors of Harrogate
Ingredients	Black African and Indian Teas
Flavor	English Breakfast
Item Form	Bagged

Providing product options

# Making Use of the Graph Structure



KitchenAid KSM150PSE Artisan Tilt-Head Stand Mixer with Pouring Shield, 5-Quart, Empire Red

by KitchenAid

★★★★★ 6,331 customer reviews | 972 answered questions

List Price: \$429.99

Price: **\$249.99 & FREE Shipping**

You Save: **\$180.00 (42%)**

Item is eligible for 6 Month Special Financing with your Amazon.com Store Card. [Learn more](#)

**Note:** Not eligible for Amazon Prime. Available with free Prime shipping from [other sellers on Amazon](#).

**Only 14 left in stock.**

**Estimated Delivery Date:** July 28 - Aug. 2 when you choose Standard at checkout.

Ships from and sold by **GE Premier** in [easy-to-open packaging](#).

Color: **Empire Red**



Share   

Qty:

**\$249.99** + Frt

**Only 14 left in sto**

**Prem**

Include 2-Year I

**\$14.99**

 Add to Cart

[Turn on 1-Click order!](#)

**Ship to:**

KEVIN DAVENPOF

[Add to List](#)

[Add to Wedding f](#)

**Other Sellers**

**\$264.99**

 Prime

Sold by: Amazon.com

**\$264.99**

+ Free Shipping

Sold by: Marcus AV

**\$289.00**

 Prime

Sold by: goldentech

## Similar But Different

More Capacity



[See more choices](#)

[KitchenAid KSM150PSE Artisan](#)

More Attachments



[See Color Options](#)

[KitchenAid KP26M1XER 6](#)

Different Brand



[See Color Options](#)


[Hamilton Beach 63232 Electric](#)

Richer and deeper product recommendation

# Making Use of the Graph Structure

Deeper product search

All ▾ k-cups dunkin donuts dark 🔍



**Dunkin Donuts Dunkin Dark, Dark Roast Coffee K-Cups For Keurig K Cup Brewers (96 Count)**  
★★★★★ ▾ 18  
\$73<sup>92</sup> (\$73.92/Count)  
✓prime FREE Delivery Tue, May 12  
More Buying Choices  
\$69.98 (7 new offers)  
96 Count

**Dunkin Donuts K-cups Dark Roast - 48 K-cups**  
★★★★★ ▾ 112  
\$38<sup>69</sup> (\$38.69/Count)  
✓prime FREE Delivery Fri, May 8  
More Buying Choices  
\$28.00 (7 new offers)

**Dunkin' Donuts Dark K Cup Pods, Dark Roast Coffee, for Keurig Brewers, 60Count**  
★★★★★ ▾ 55  
\$35<sup>99</sup> (\$0.60/Count)  
Save 5% more with Subscribe & Save  
✓prime FREE Delivery Sun, May 10  
60 Count (Pack of 1)

**Dunkin Donuts Dunkin Dark Coffee K-Cups For Keurig K Cup Brewers (96 Count) - Packaging May Vary**  
★★★★★ ▾ 79  
\$70<sup>57</sup> (\$0.74/Count)  
✓prime FREE Delivery Sat, May 9  
More Buying Choices  
\$66.95 (8 new offers)

**Dunkin Donuts K-cups Dark Roast - 24 Kcups for Use in Keurig Coffee Brewers**  
★★★★★ ▾ 140  
\$20<sup>15</sup> (\$0.84/Count)  
✓prime FREE One-Day Get it Tomorrow, May 5  
More Buying Choices  
\$13.20 (8 new offers)

# Product Knowledge Graph Embeddings

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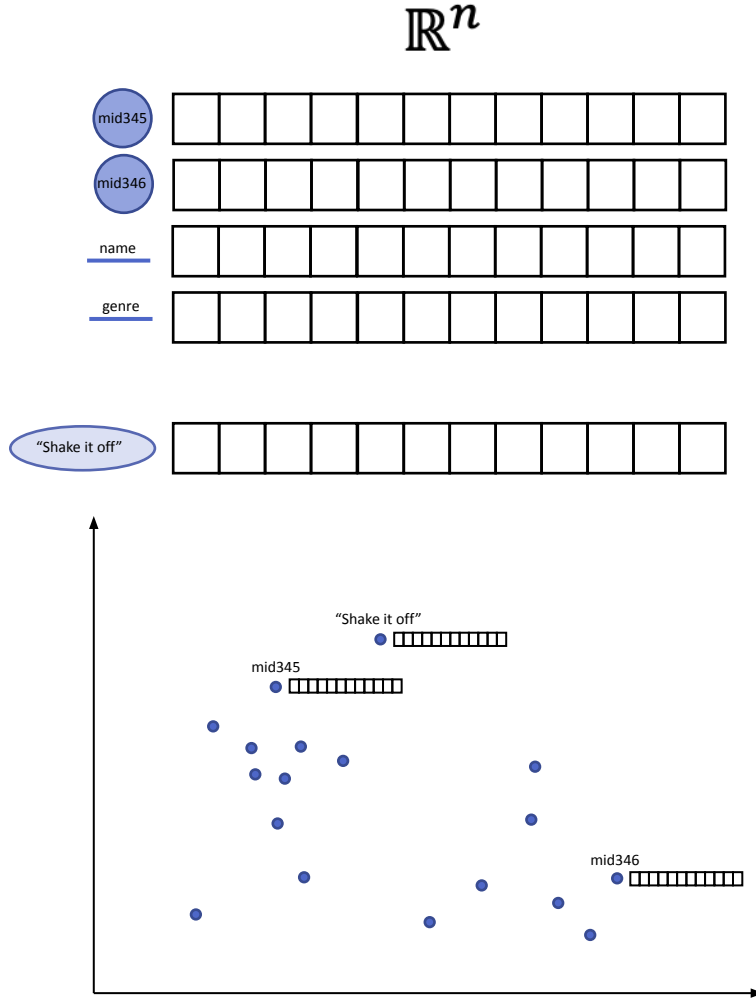
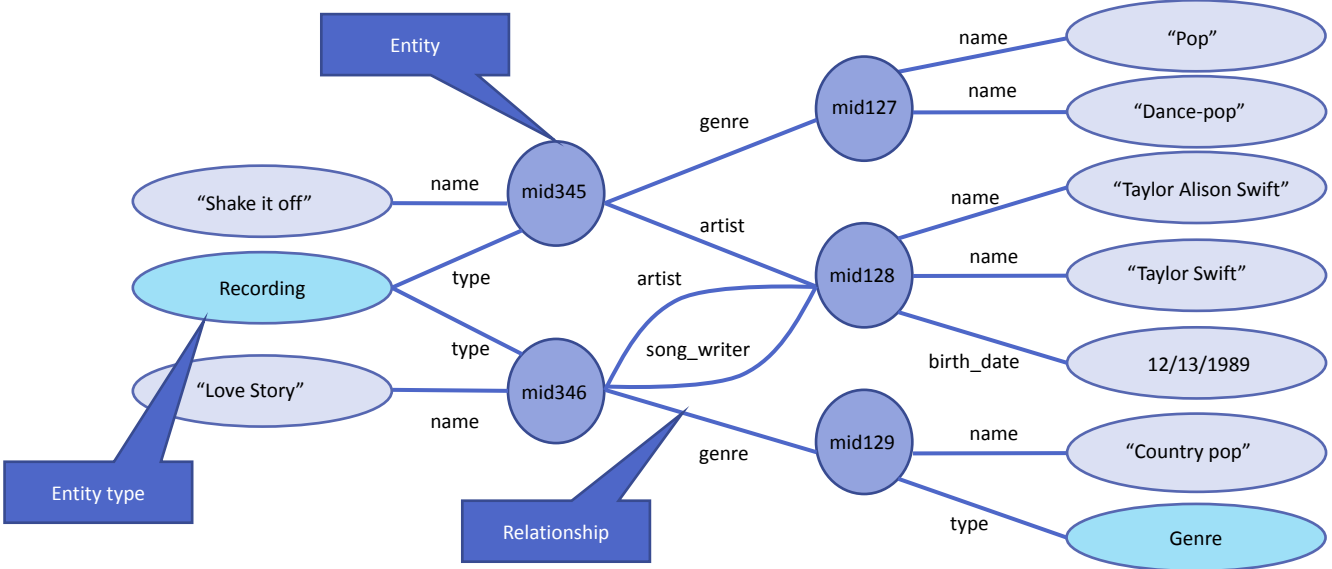
Overview, Definition, Applications



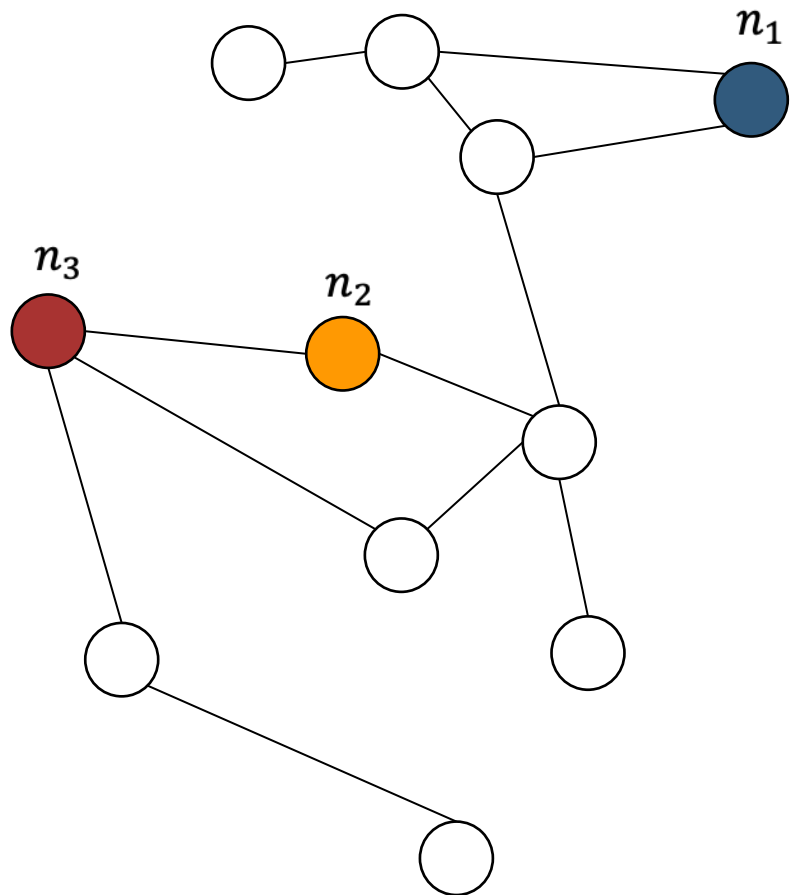
# Knowledge Graph Embeddings

- The various KG applications make repeated use of knowledge graph embeddings (KGE).
- We will therefore recap the topic of KGE, then highlight the specificities of product knowledge graph embeddings (PKGE).
- KGE, and PKGE, also can have several standalone applications, that we highlight in this section.

# Knowledge Graph Embedding



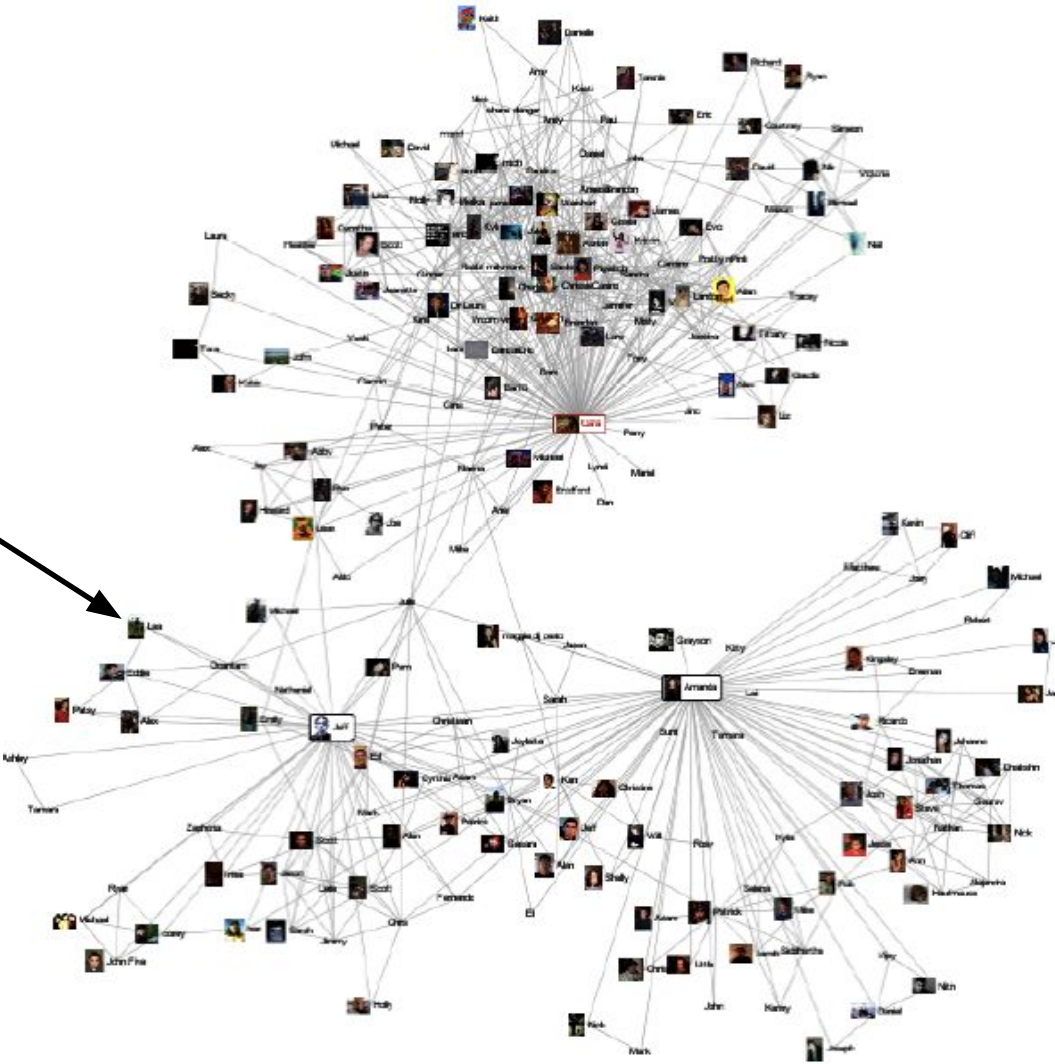
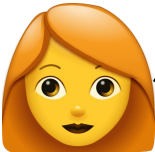
# Node Classification



- If we know  $n_1$  is republican.
- And  $n_3$  is democrat.
- What can we say about  $n_2$ ?

# Link Prediction

Does she know Jay Leno?



# PKGE, Compared to KGE

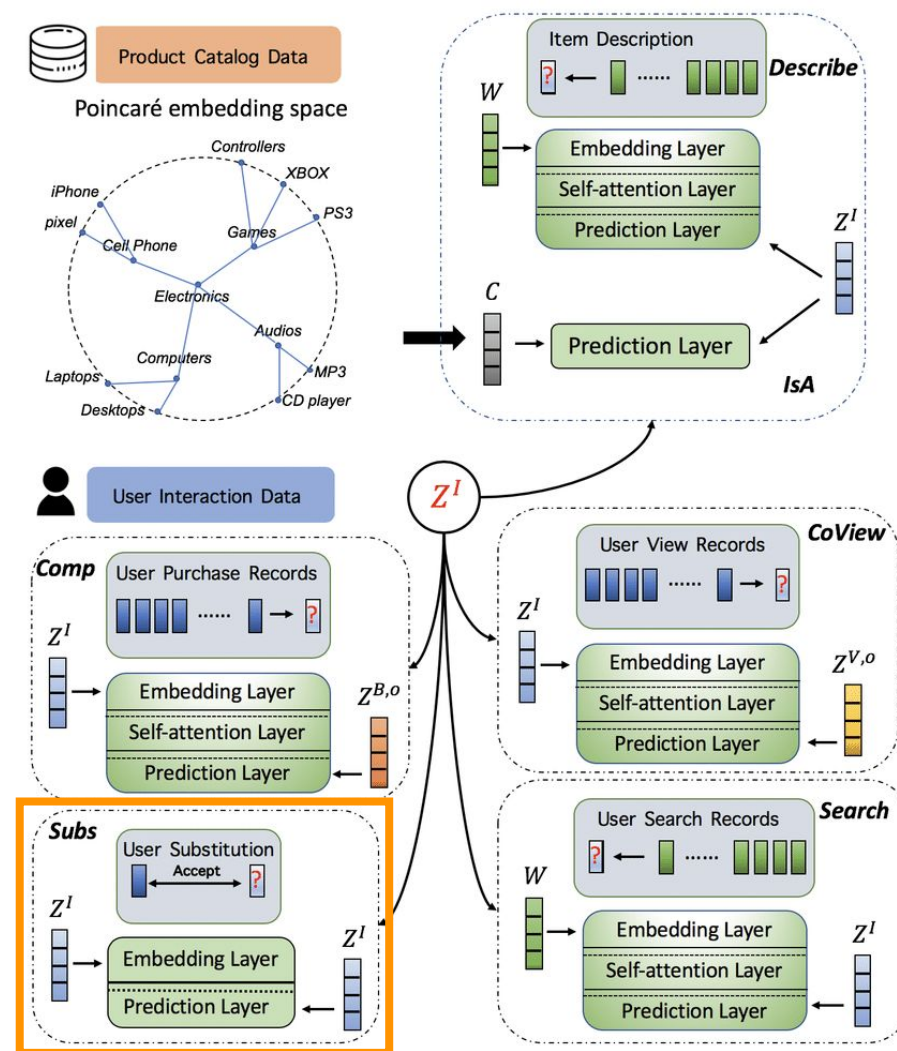
<b>Text-heavy product description</b>	<ul style="list-style-type: none"><li>• Descriptions provide a wealth of additional textual information.</li><li>• Requires explicit interaction of model with natural language.</li></ul>
<b>User activity</b>	<ul style="list-style-type: none"><li>• User activities, like product search, provide additional signals.</li><li>• Provide relations like product complement, co-view and substitute</li></ul>
<b>Noise</b>	<ul style="list-style-type: none"><li>• KGE facts are assumed to be well established and plausible.</li><li>• Facts in PKGE can be more noisy.</li></ul>
<b>Hierarchical structure</b>	<ul style="list-style-type: none"><li>• Hard to be embedded into Euclidean spaces.</li><li>• Can utilize hierarchical embeddings, like Poincaré embeddings.</li></ul>

# Product Knowledge Graph Embeddings

- Xu et al., 2020, presented a PKGE model, that is tailored to the specificities of the retail domain.
- Knowledge graph of products, words and category labels as entities and relations as edges
- Their embedding model showed improvement in tasks including:
  - Search ranking.
  - Recommendation.
  - Knowledge completion.

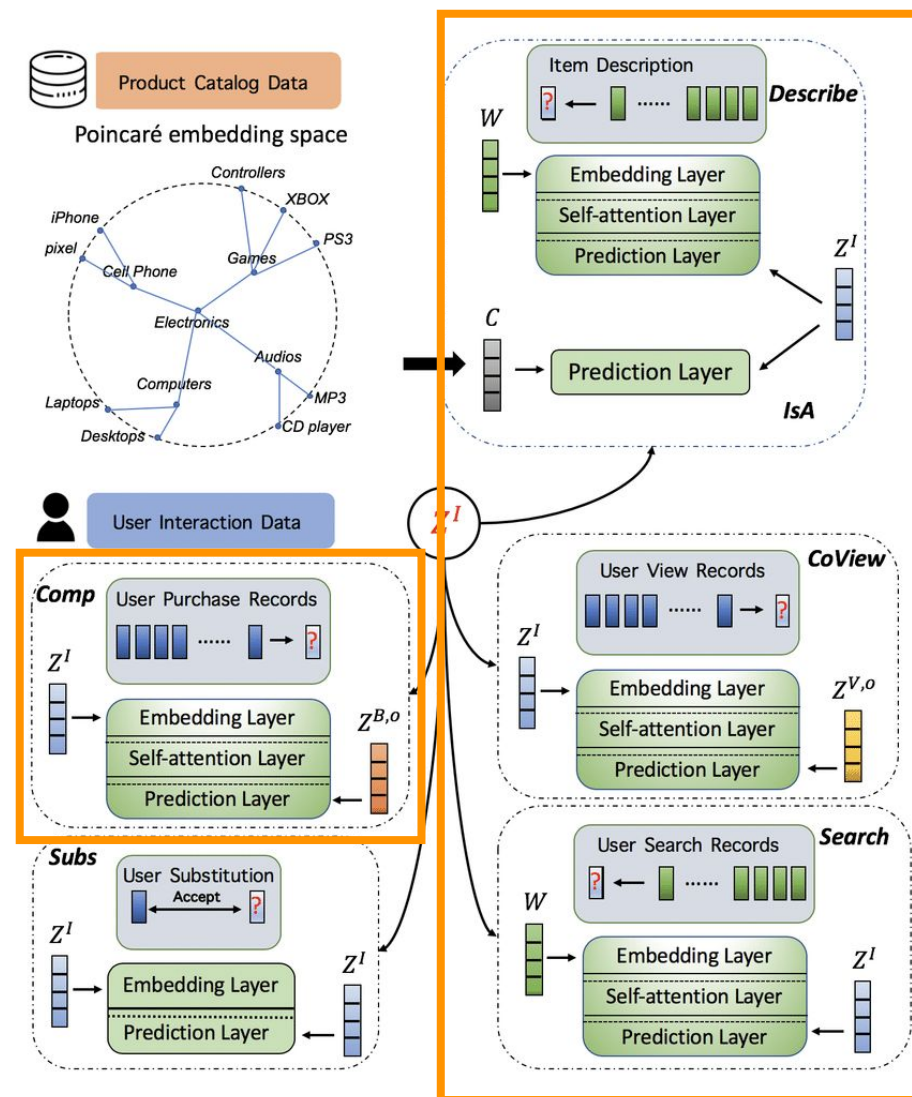
# Product Knowledge Graph Embeddings

- **Modelling substitute Relation:** Similar products should have similar embeddings.
  - Product substitute logs can represent such similarity.



# Product Knowledge Graph Embeddings

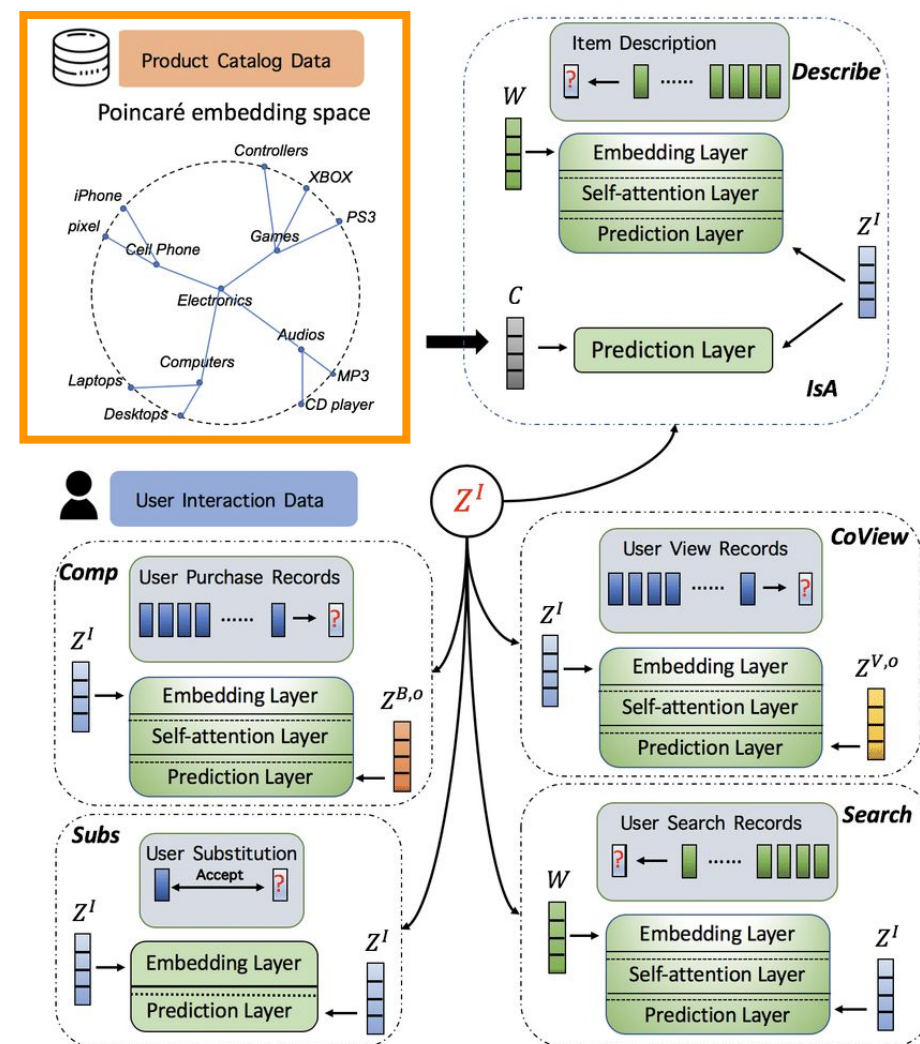
- **Modelling substitute Relation:** Similar products should have similar embeddings.
  - Product substitute logs can represent such similarity.
- **Self-attention mechanism** for noise-robust handling for complement, co-view, describe and search Relations.





# Product Knowledge Graph Embeddings

- **Modelling substitute Relation:** Similar products should have similar embeddings.
  - Product substitute logs can represent such similarity.
- **Self-attention mechanism** for noise-robust handling for complement, co-view, describe and search Relations.
- **Poincaré embedding** for the category hierarchy



# Product Knowledge Graph Applications

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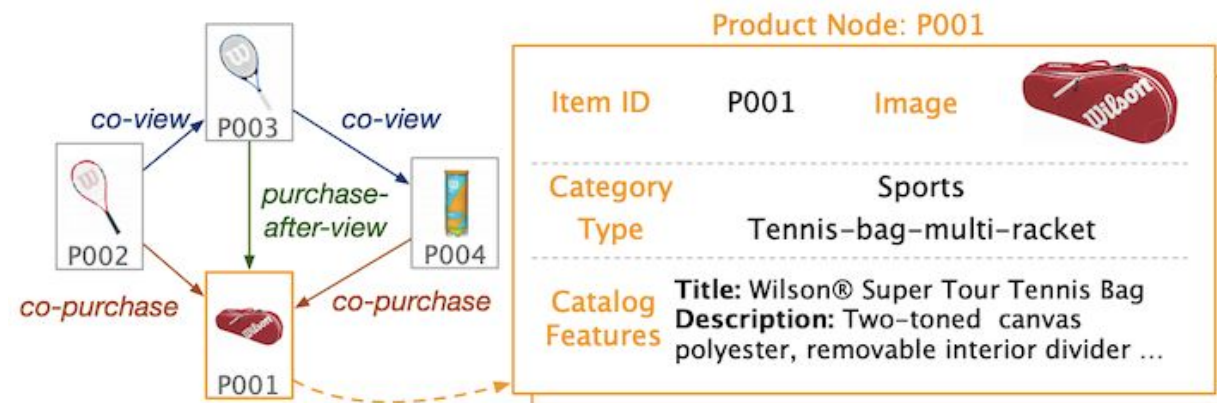
Recommendation Systems, Search and Question Answering

# Recommendation Systems

- Recommendation systems play a major role in eCommerce.
  - Enhance customer experience.
  - Drive revenue.
  - Maintain engagement.
  - Among others.
- PKGs play a big role in improving overall recommendation quality, in terms of:
  - Recommendation accuracy.
  - Recommendation diversity.
  - And recommendation explainability.

# Product Recommendation Systems

- We can think of different variations of product recommendations:
  - Product substitutes.
  - Related products.
  - Complementary product recommendation.
- **Behavior-based Product Graph (BPG):**
  - BPGs can be very useful for recommendation systems.
  - BPG is constructed with nodes as items with catalog features (type, etc) and edges as pairwise relations based on customer behavior.



# Specificities of Product Recommendation Systems

## Recommendation diversity

- Recommendation diversity is critical for eCommerce.
- Making related recommendations only is not enough.

## Complementary recommendations

- Simple co-purchase patterns might not be enough.
- Need semantic signal for complementary recommendations.

## Recommendation interpretability

- Explicit paths in KGs provide a better explainability potential.

## Hierarchical structure

- The product taxonomy and categories help in all previous issues.

# Complementary Product Recommendation

- Complementary product recommendation (CPR) aims at providing product suggestions that are often bought together.
- Co-purchased products are not always complementary.

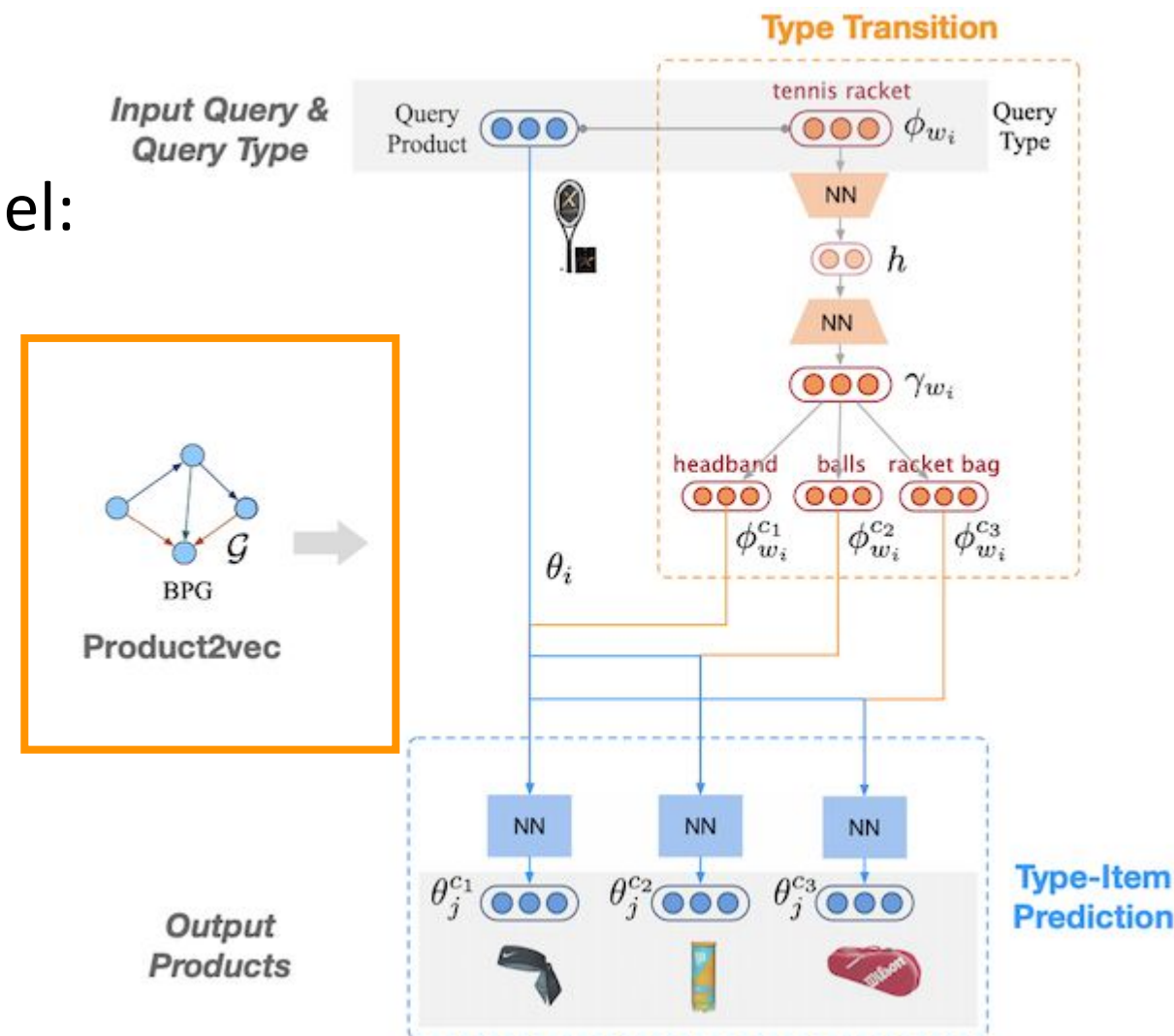
**Complementary  
recommendation  
systems**



# Product Complement Systems

Main components in Hao et al. 2020 complementary recommendation model:

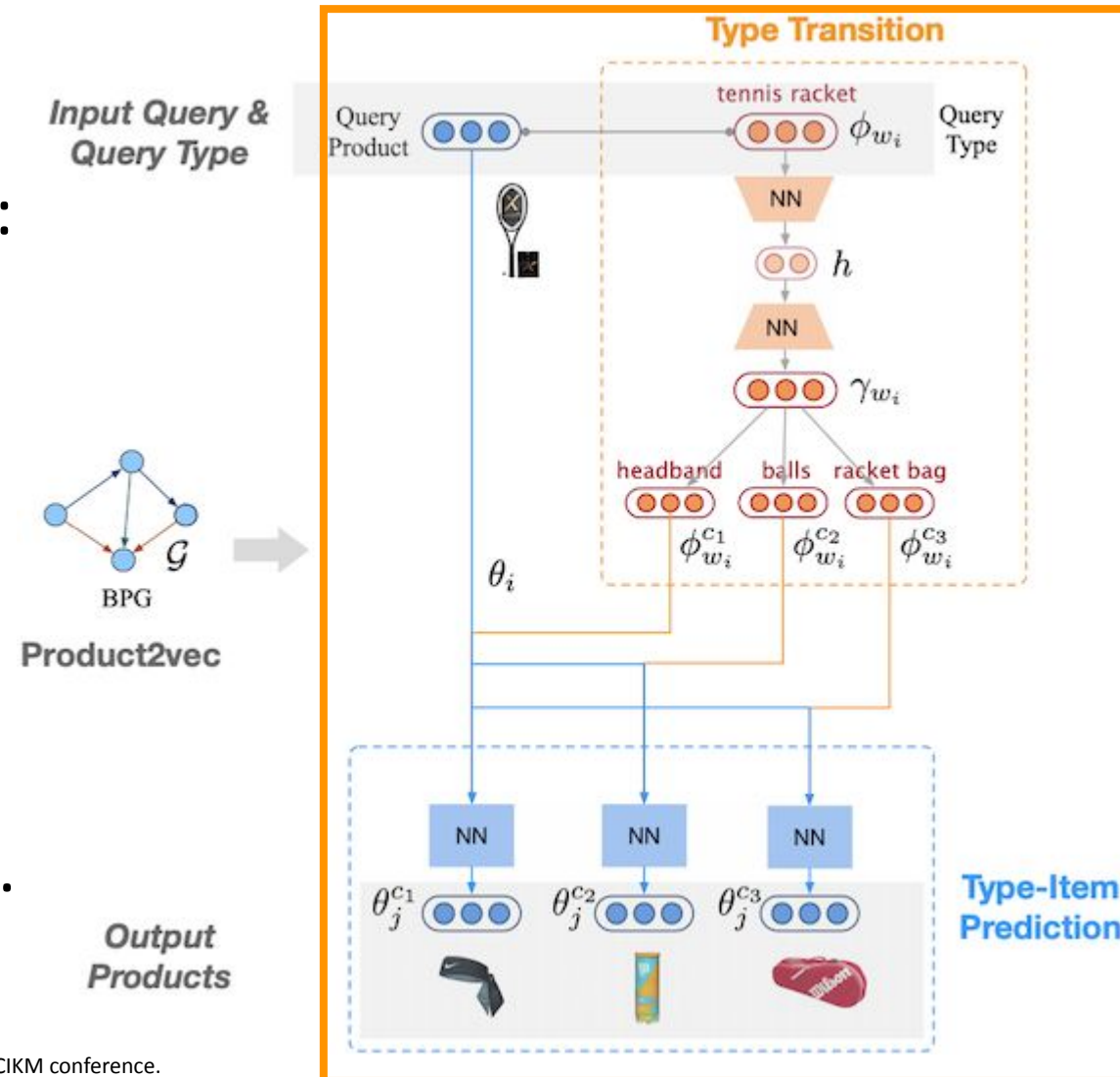
- Product2vec: Pretrained product embeddings based on customer behavior data.



# Product Complement Systems

Main components in Hao et al. 2020 complementary recommendation model:

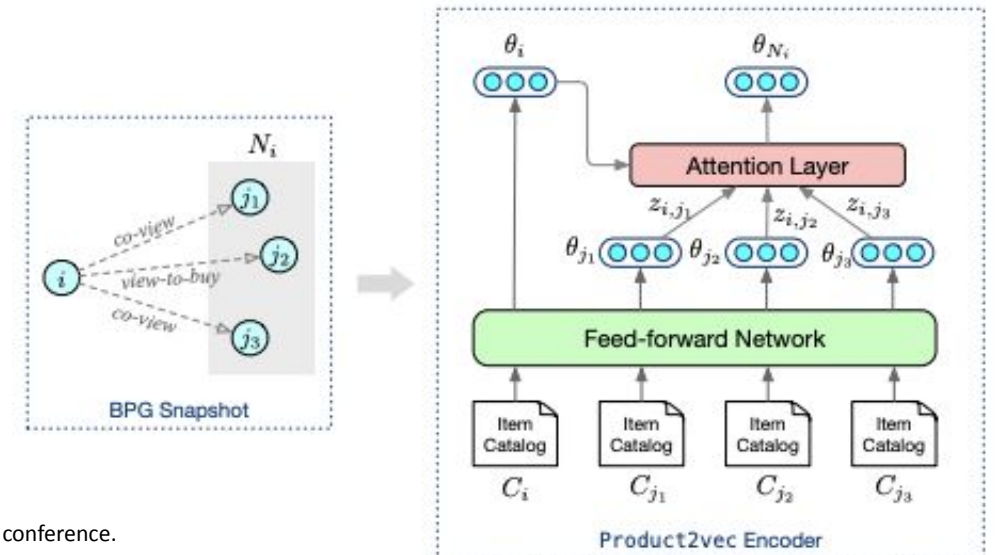
- Product2vec: Pretrained product embeddings based on customer behavior data.
- Type transition: complementary product type prediction task (as opposed to actual products).
- Item prediction: Complementary product prediction from product type.





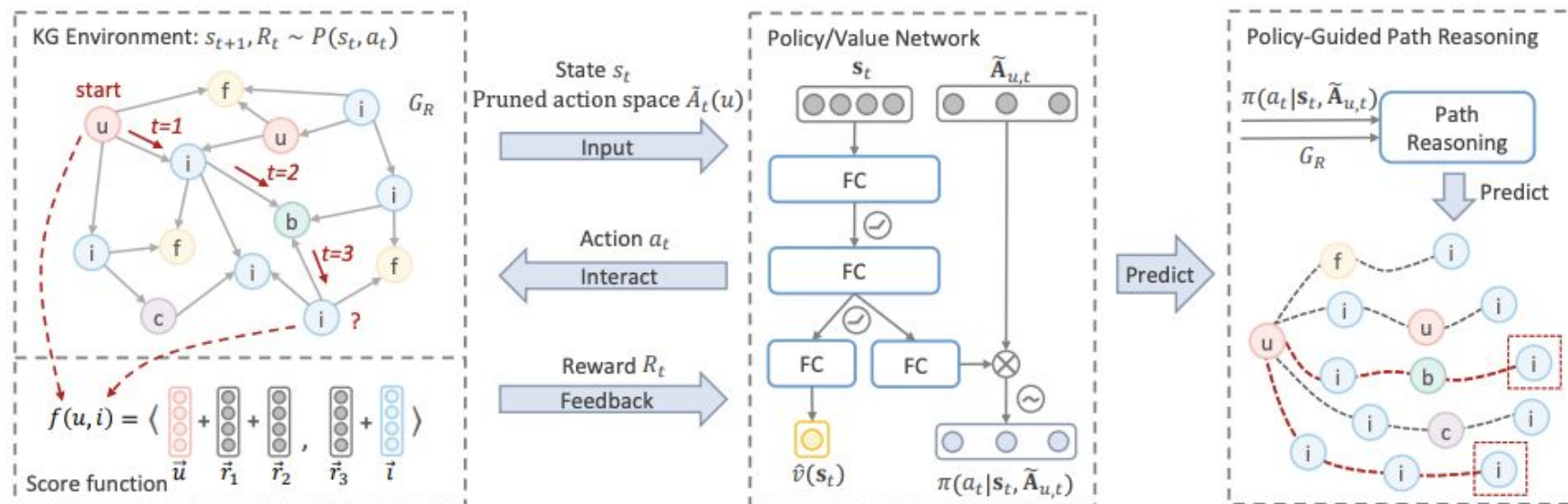
# Product2Vec

- Just like the other “\*2Vec” family. Learns pretrained representations for products that preserve similarities.
- Leverages user behavior logs, and the co-purchase relation in particular to build a graph, and use graph attention network.
- Very useful in cold-start products in many applications, especially recommendation systems.



# Explainable Product Recommendation

- The paths in PKGs also allow for explainable recommendation, through explicit reasoning.
- Xian et al., 2019, use reinforcement learning to identify recommendation paths from a user to product.



# Product Search and Question Answering

## User activity

- User search logs and purchases, product complements, co-view and substitute are very useful.

## Multilingual search

- e-Commerce platforms serve many countries with several languages.
- Ideally, should facilitate multilingual search to support scale.

## Dynamic taxonomy

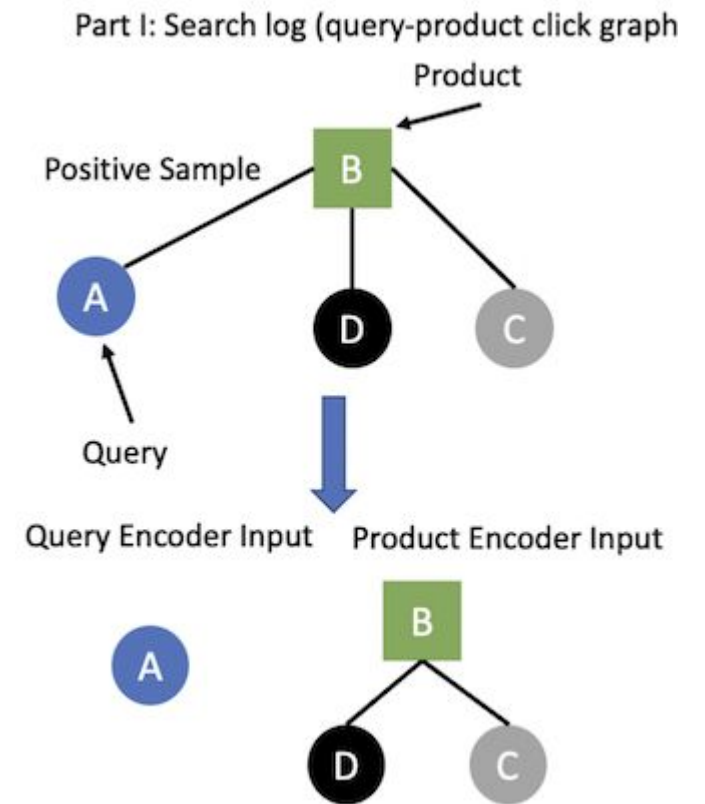
- Taxonomy enrichment and relation discovery.

## Noise

- Facts in PKG can be noisy, which can affect results.
- Importance of data cleaning.

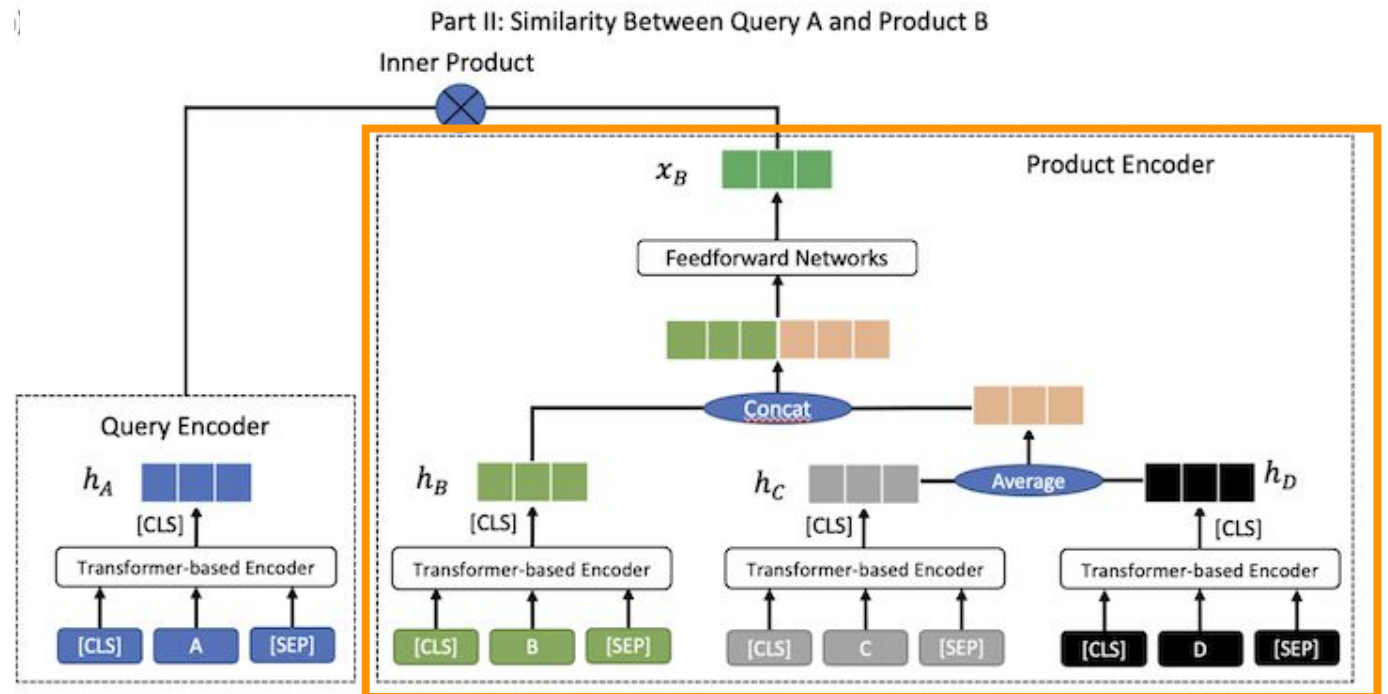
# Product Search

- Lu et al. 2020 presented a multilingual graph-based product search and retrieval model.
  - Transformer-based encoding.
- Present query-to-product relationships as a bipartite graph.
  - Product (B) to query (A, C, and D) mapping.
  - Neighbouring queries (D, C) from search log.
  - A (positive sample) used to train query encoder.



# Product Search

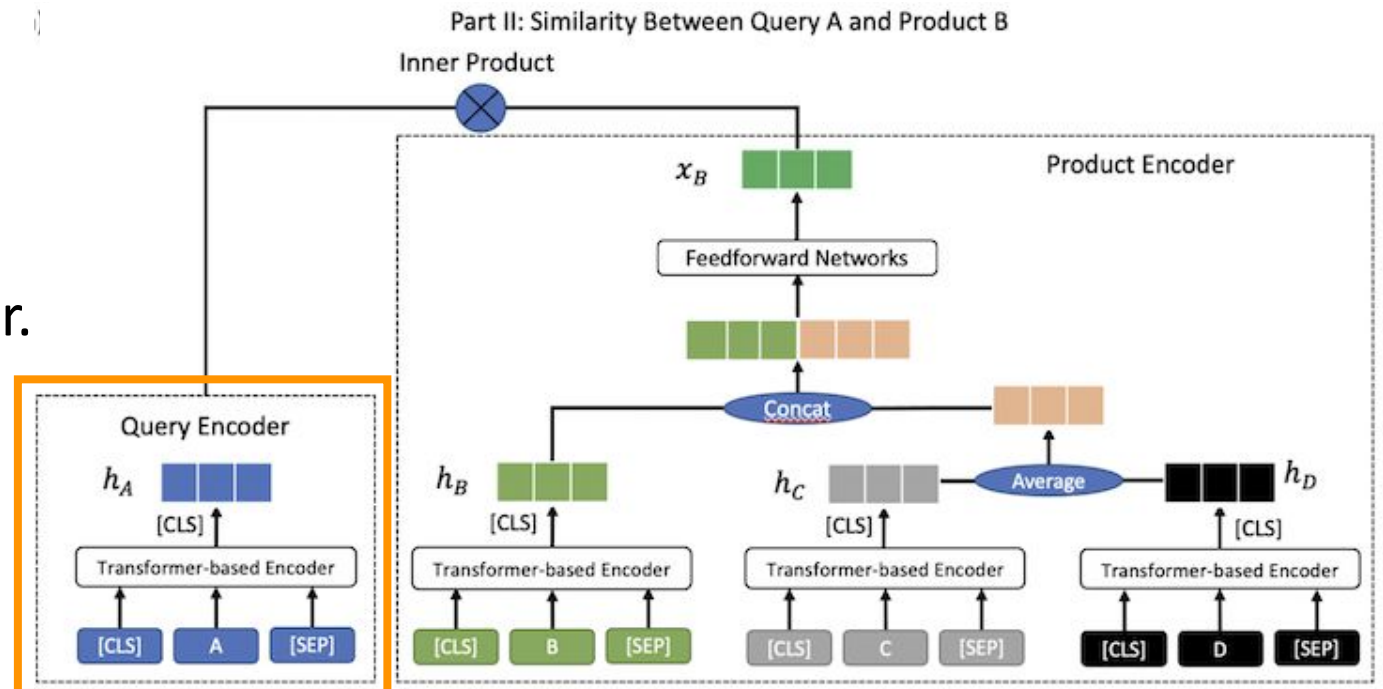
- Product encoder:
  - Takes product, and neighboring queries as input.
  - Transformer-based model.
  - Convolutional Graph Networks to learn representation.



# Product Search

- Product encoder:
  - Takes product, and neighboring queries as input.
  - Transformer-based model.
  - Convolutional Graph Networks to learn representation.

- Query encoder:
  - Transformer-based encoder for the query text.








# Product Search Challenges

- Exact match in search results, based on main query attributes, is very important in the product domain.
- Among the notable challenges facing product search is the incomplete taxonomy and overall factual knowledge.
- Completeness and scalability in PKGs help a lot on this regard. Direct access of product descriptions is also important.

# Product Search Challenges

All ▾ k-cups dunkin donuts dark 🔍

 <b>Dunkin' Donuts Original Blend</b> Medium Roast Coffee, 28 K Cups for Keurig Coffee Makers ★★★★☆ 3,395 \$38 <sup>50</sup> (\$1.44/Count) Save 5% more with Subscribe & Save ✓prime FREE Delivery Sun, May 10 88 Count	 <b>Dunkin' Donuts K-cups Dark Roast - 48 K-cups</b> ★★★★☆ 112 \$38 <sup>69</sup> (\$38.69/Count) ✓prime FREE Delivery Fri, May 8 More Buying Choices \$28.00 (7 new offers)	 <b>Dunkin' Donuts Dark K Cup Pods, Dark Roast Coffee, for Keurig Brewers, 60Count</b> ★★★★☆ 55 \$35 <sup>99</sup> (\$0.60/Count) Save 5% more with Subscribe & Save ✓prime FREE Delivery Sun, May 10 60 Count (Pack of 1)	 <b>Dunkin Donuts Dunkin Dark Coffee K-Cups For Keurig K Cup Brewers (96 Count) - Packaging May Vary</b> ★★★★☆ 79 \$70 <sup>57</sup> (\$0.74/Count) ✓prime FREE Delivery Sat, May 9 More Buying Choices \$66.95 (8 new offers)	 <b>The Original Donut Shop Keurig Single-Serve K-Cup Pods, Regular Medium Roast Coffee, 72 Count</b> ★★★★☆ 9,914 \$29 <sup>99</sup> (\$0.42/Count) Save 5% more with Subscribe & Save ✓prime FREE One-Day Get It Tomorrow, May 5 72 Count
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# Conversational Product Search

- A natural extension to search and recommendation applications.
- Personal assistants are pervasive now, so inquiring about products, and asking for product recommendations, is a logical skill to add.
- Same setup as search techniques, with iterative turns, powered by product attributes, to further identify most relevant product.