CS-4053 Recommender System

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Lecture 9: Graph-based Recommender Systems

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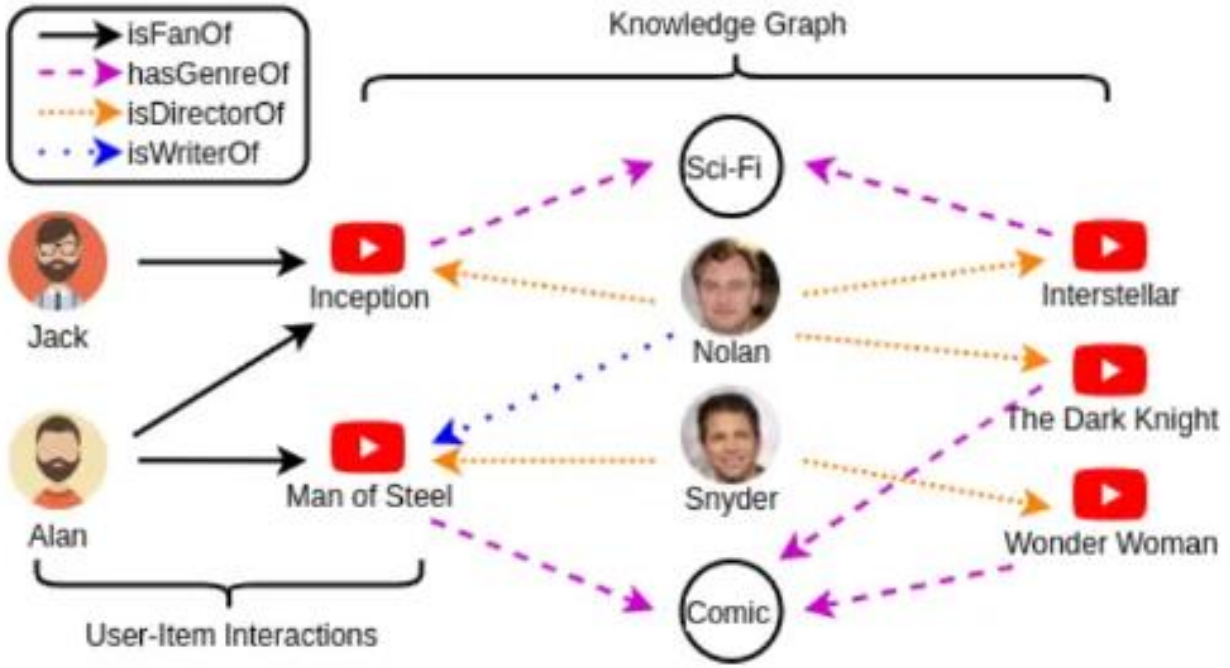
Knowledge Graph-based System

- A knowledge graph-based system leverages graph data structure to represent users, items, and their relationships
- It uses this rich network of interconnected data to make personalized recommendations
- Interest information of users and similarity scores are accumulated and stored directly in the graph structure

Knowledge Graph-based System



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Knowledge Graph-based System

- **Diversity**
  - KGs represent semantically rich relations between entities
  - Different aspects of user preference e.g., director, genre can be used to provide tailored recommendations

- **Scalability**
  - Graph-based systems do not need to construct a sparse matrix to predict similarity scores
  - User's preference information and similarity calculation values are accumulated and stored in the graph structure itself

Knowledge Graph-based System

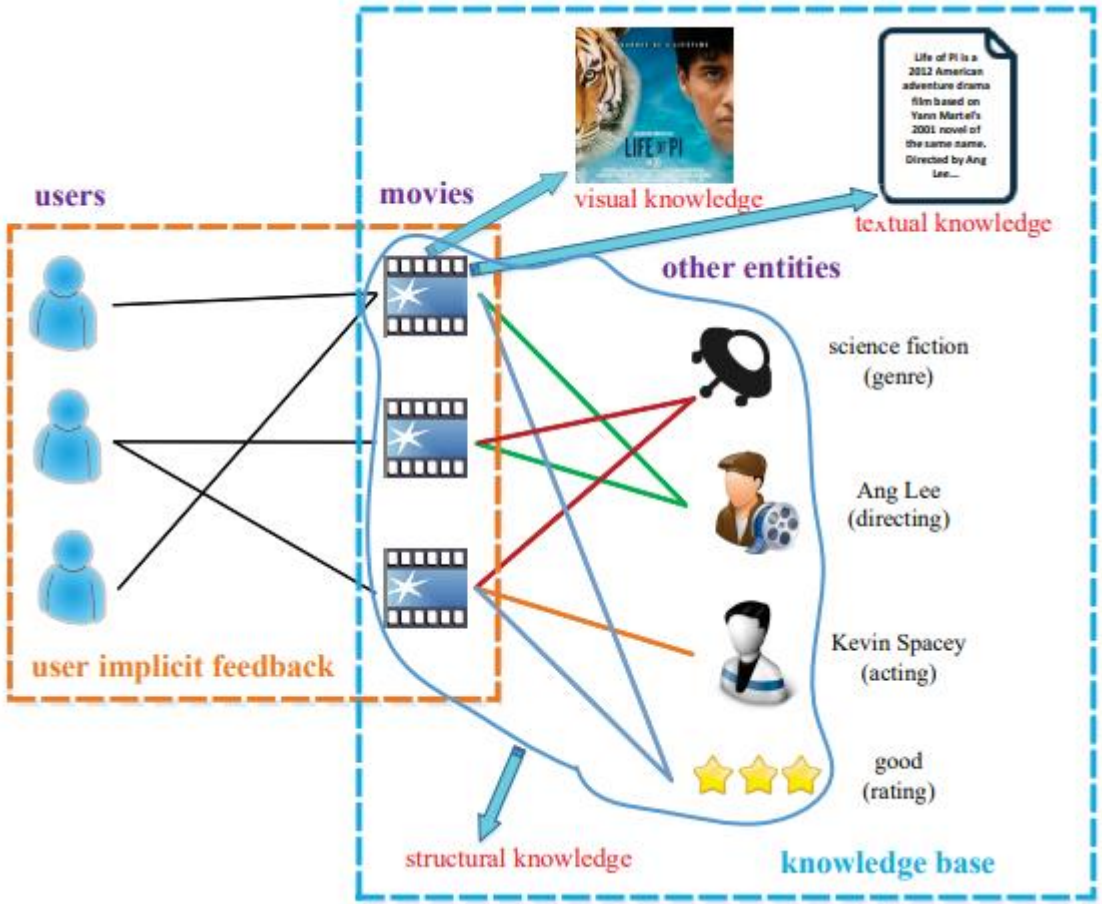
- There are three approaches for knowledge graph-based recommendations
  - Embedding-based[1]
  - Path-based[2]
  - RippleNet[3]

[1] http://dx.doi.org/10.1145/2939672.2939673

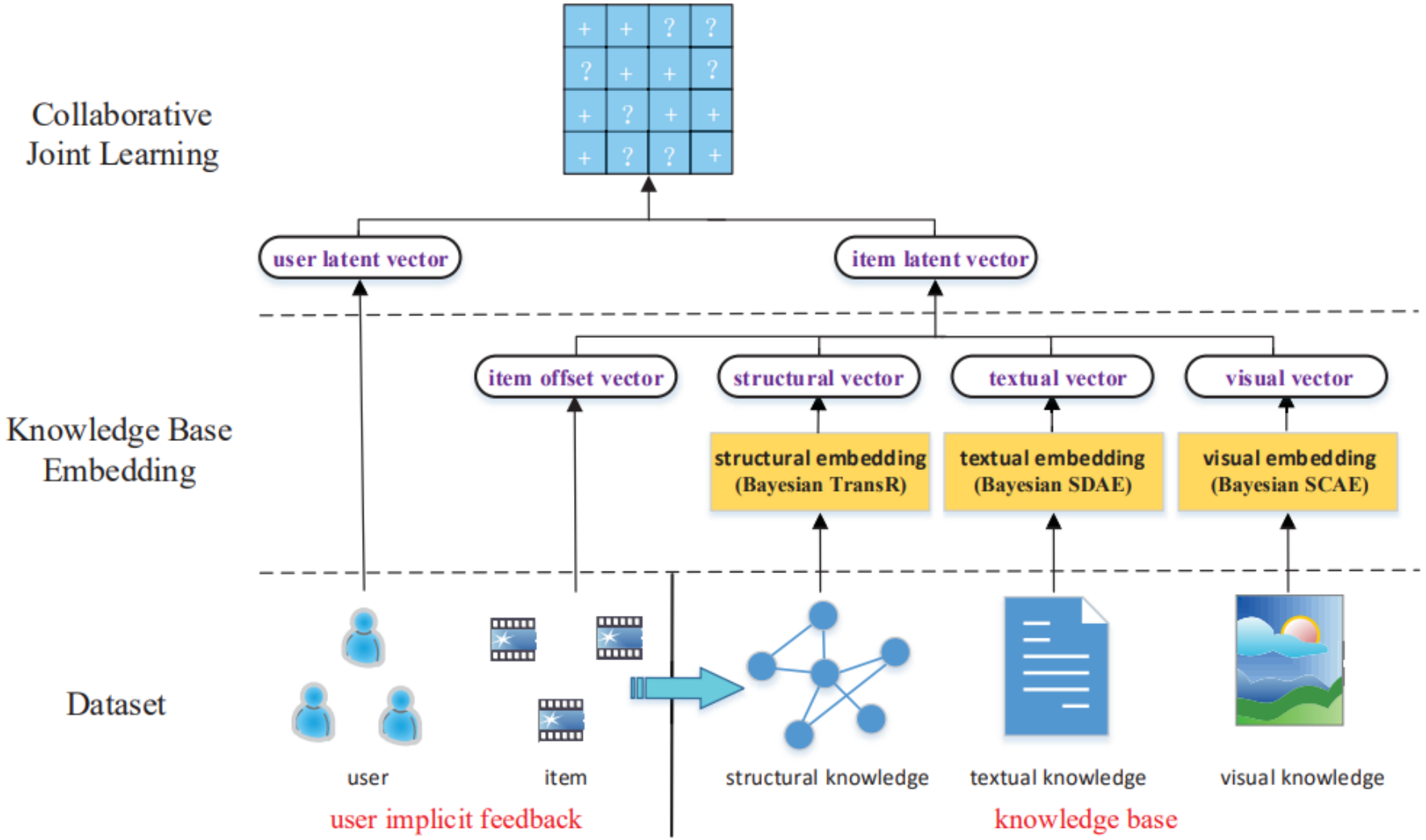
Embedding-based KG Recommendation

- Pre-process KG using knowledge graph embedding algorithms
  - **For *structural* knowledge:** TransR embedding
  - **For *textual* knowledge:** Word2Vec, Stacked Denoising Autoencoder
  - **For *visual* knowledge:** Stacked Convolutional Autoencoder
- The generated embeddings become input to joint collaborative (content) filtering
- Use cosine similarity (or some other measure) for finding distance of **u** to $\mathbf{v}_i$ *(i=1, 2, …, n)*

Embedding-based KG Recommendation



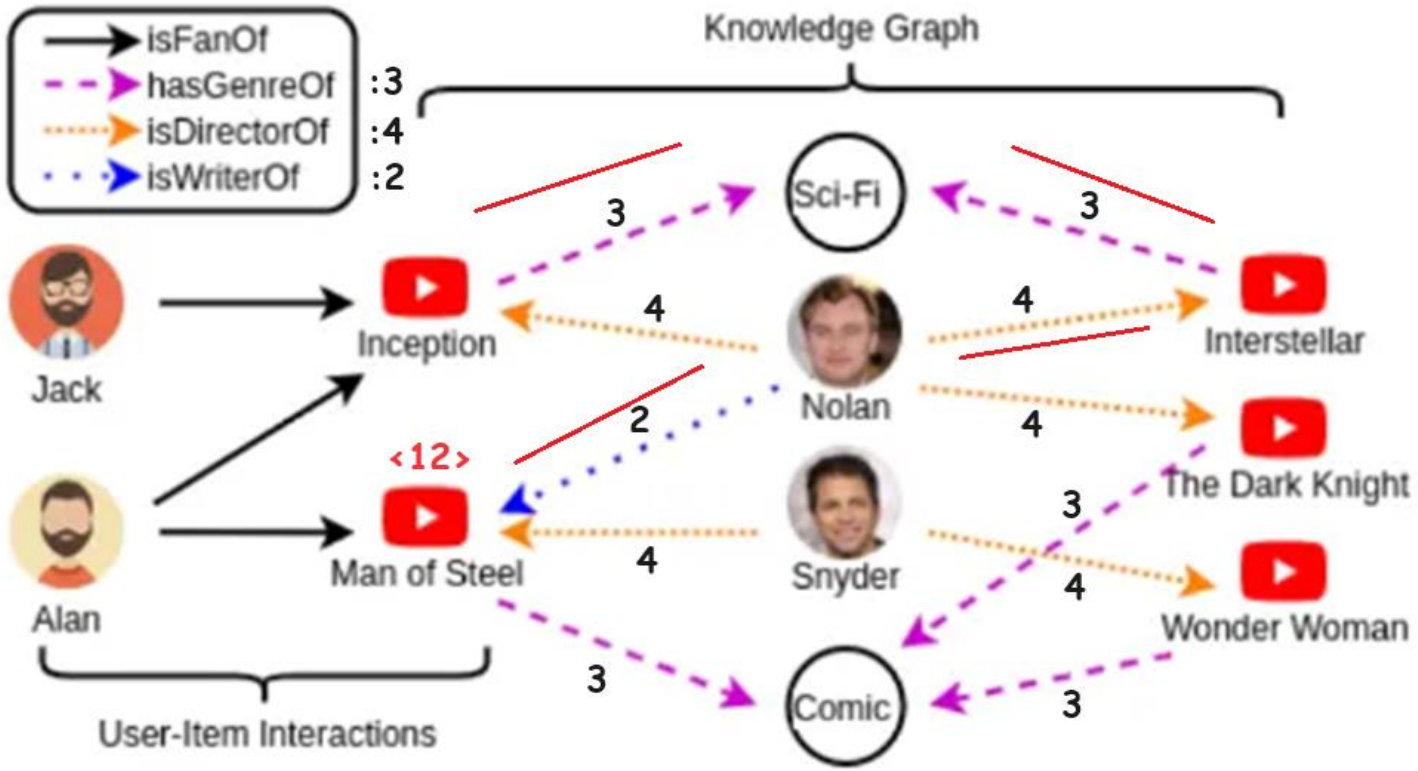
Embedding-based KG Recommendation



Path-based KG Recommendation

- For an active user, traverse a path from each of the *k* top-rated items of the user
- Each edge is assigned a feature score
- The path follows edges representing knowledge about the item
- Each edge is visit once and its feature score is added to total path score
- For each path of an unrated item:
  - It ends on an unrated item and its path score is recorded
  - The maximum path score across all paths become the item utility value
- The top-*k* items with maximum utility values are recommended

Path-based KG Recommendation



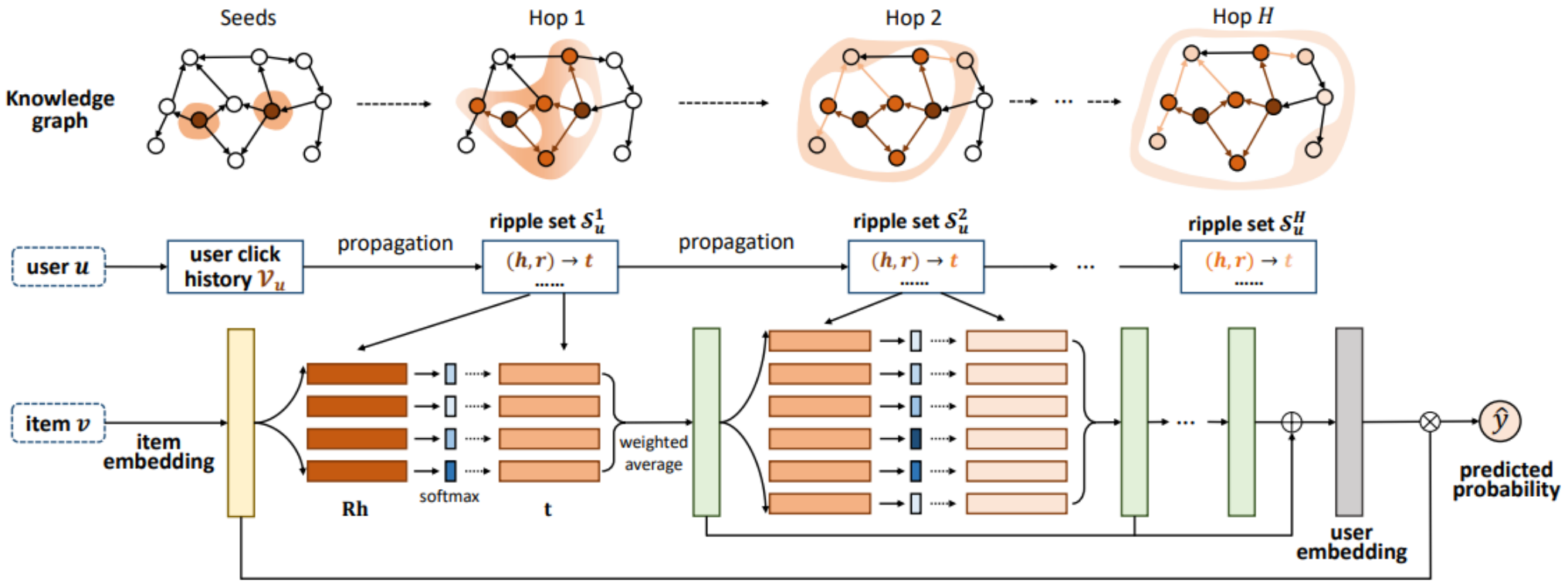
- Domain knowledge is used to assign feature scores
- The path score in this example is 12

Image Credits: https://shorturl.at/mnqEH

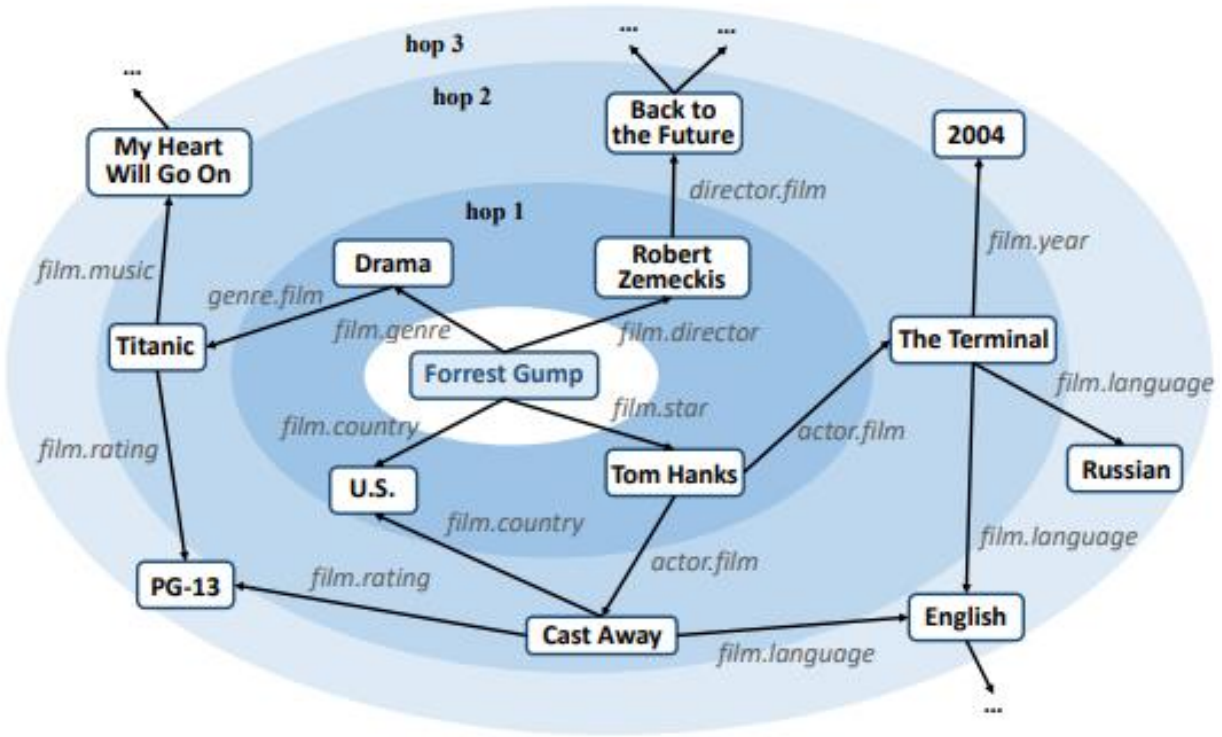
RippleNet

- RippleNet takes a user ***u*** and an item ***v*** as input, and outputs the predicted probability that user ***u*** will click item ***v***
- For the input user ***u***, his historical set of interests V_u is treated as seeds in the KG, then extended along links to form multiple ripple sets
- A ripple set is the set of knowledge triples that are k-hop(s) away from the seed set V_u. These ripple sets are used to interact with the item embedding iteratively for obtaining the responses of user ***u*** with respect to item ***v***, which are then combined to form the final user embedding
- Lastly, we use the embeddings of user ***u*** and item ***v*** together to compute the predicted probability

RippleNet


Seeds
Hop 1
Hop 2
Hop H
Knowledge graph
user u
user click history $\mathcal{V}_u$
propagation
ripple set $\mathcal{S}_u^1$
$(h,r) \rightarrow t$
propagation
ripple set $\mathcal{S}_u^2$
$(h,r) \rightarrow t$
ripple set $\mathcal{S}_u^H$
$(h,r) \rightarrow t$
item v
item embedding
Rh
softmax
t
weighted average
user embedding
predicted probability
$\hat{y}$

RippleNet


hop 3
hop 2
hop 1
My Heart Will Go On
Back to the Future
2004
director.film
film.year
film.music
Drama
Robert Zemeckis
genre.film
film.genre
film.director
Titanic
Forrest Gump
The Terminal
film.language
film.star
film.country
actor.film
film.rating
U.S.
Tom Hanks
Russian
film.country
film.language
actor.film
PG-13
film.rating
Cast Away
English
film.language