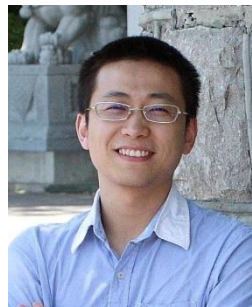


# *COT: Contextual Operating Tensor for Context-aware Recommender Systems*



**Qiang Liu**



**Shu Wu**



**Liang Wang**

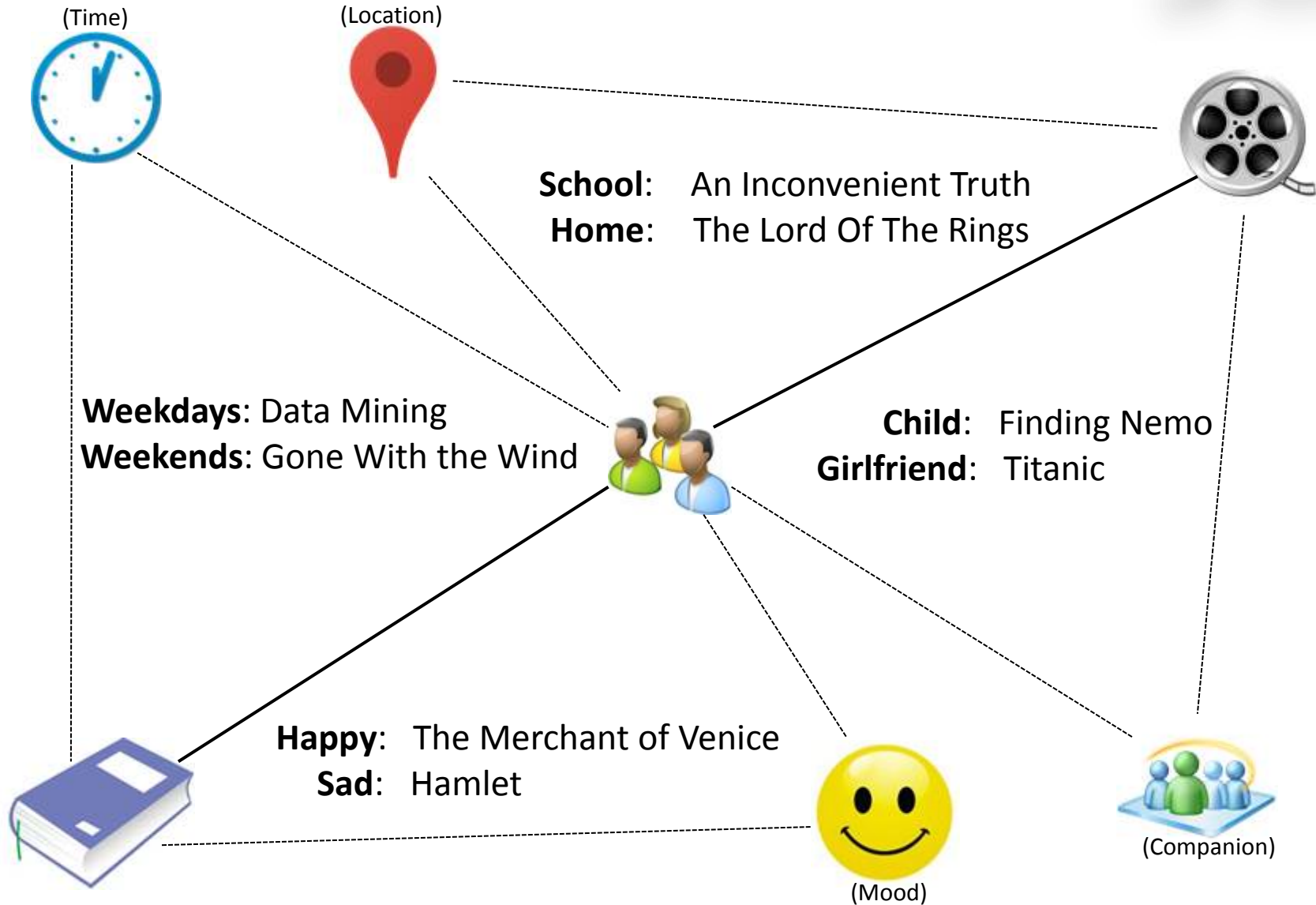
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National Lab of Pattern Recognition (NLPR)  
Institute of Automation, Chinese Academy of Sciences (CASIA)*

**@AAAI 2015, Austin, Jan 28, 2015**

# Information Overload



# Context-awareness



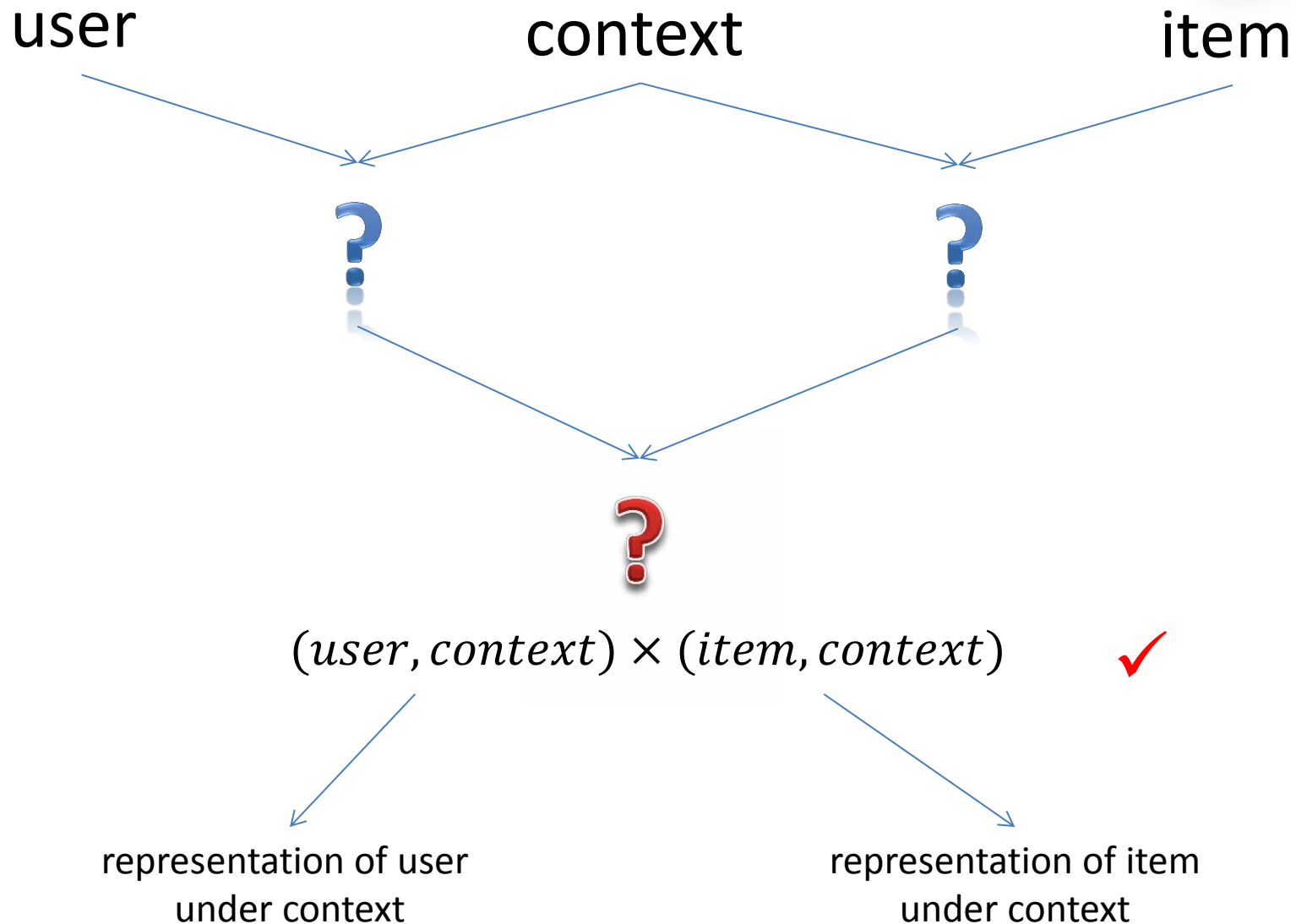
- Multiverse recommendation<sup>1</sup>:  
 $\text{user} \times \text{item} \times \text{context}$
- Factorization machine (FM)<sup>2</sup>:  
 $\text{user} \times \text{item} + \text{user} \times \text{context} + \text{item} \times \text{context}$
- Contexts are treated as other dimensions similar to the dimensions of users and items.
- Calculate the similarity among user, item and context.

$\text{user} \times \text{context}$  ✘

$\text{item} \times \text{context}$  ✘

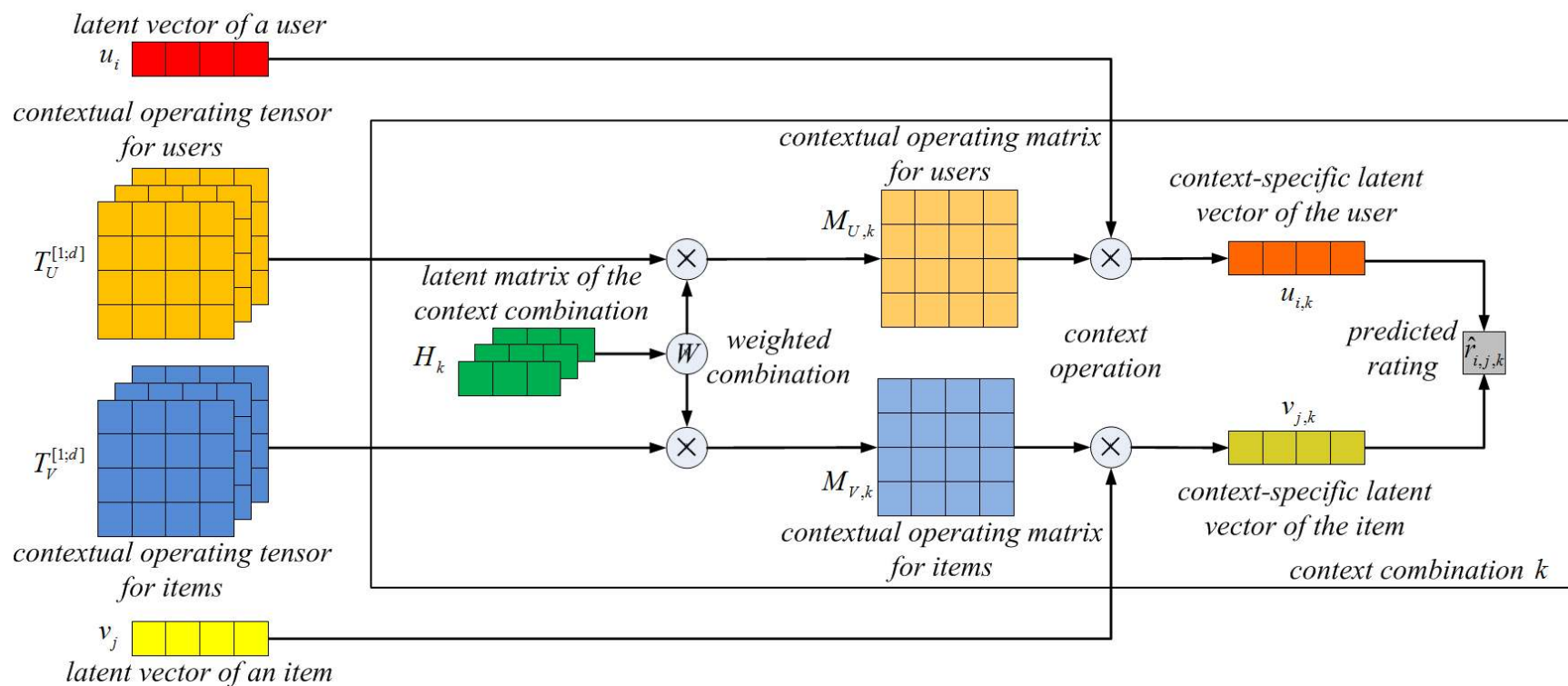
(1) Karatzoglou et al, Multiverse recommendation: n-dimensional tensor factorization for context-aware collaborative filtering.

(2) Rendle et al, Fast context-aware recommendations with factorization machines.



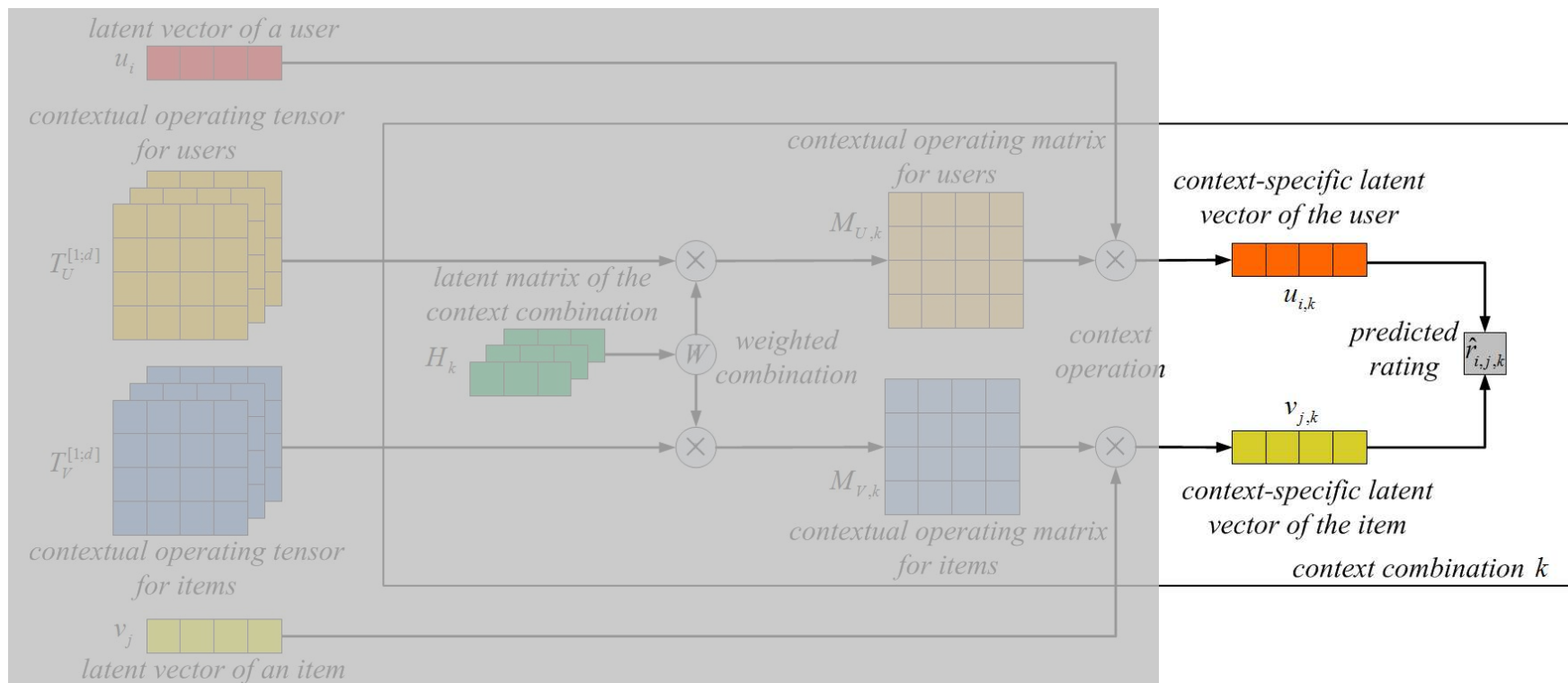
# Overview of COT

Contextual operating tensors and latent vectors of entities are shown on the left side, and the computational procedure under each context combination is illustrated in the square.



## Matrix Factorization with Biases:

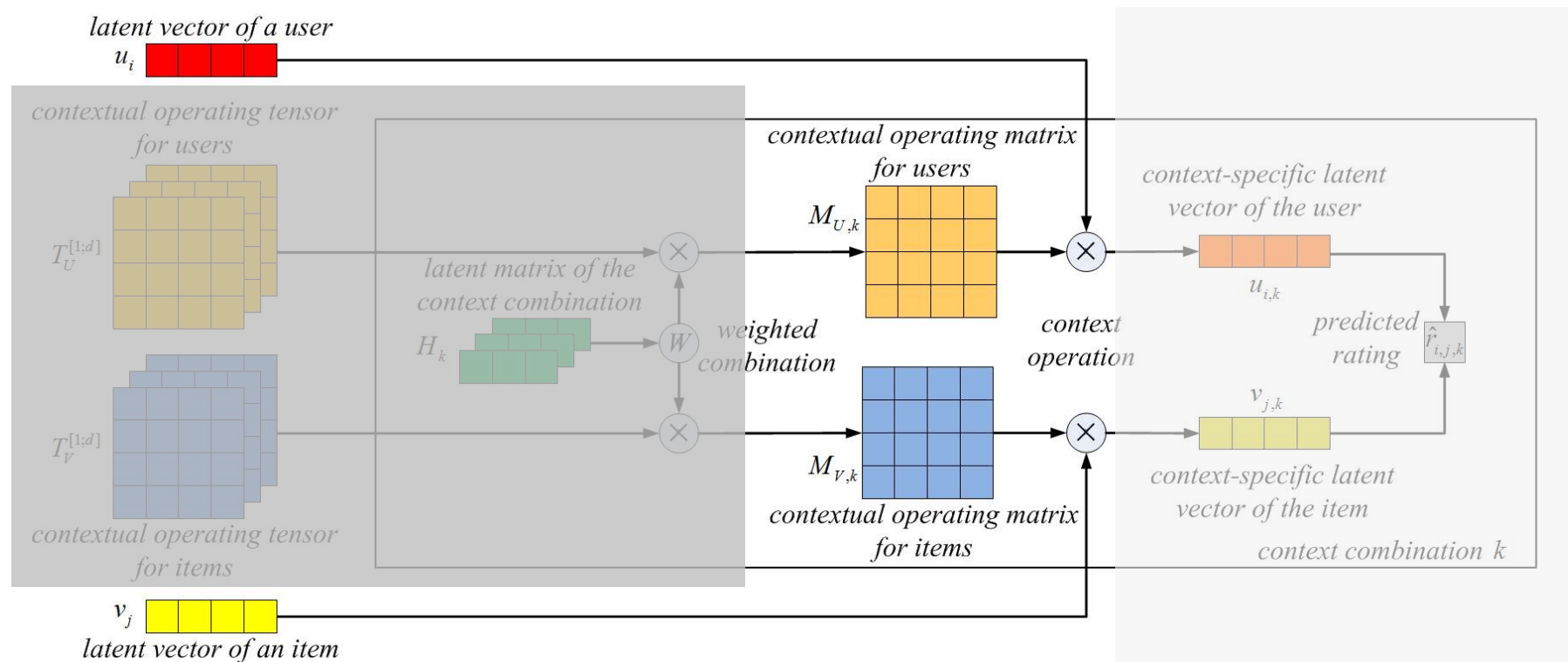
$$\hat{r}_{i,j,k} = \omega_0 + \omega_i + \omega_j + \sum_{m=1}^n \omega_{m,k} + u_{i,k}^T v_{j,k}$$



## Contextual Operating Matrix:

$$u_{i,k} = M_{U,k} u_i$$

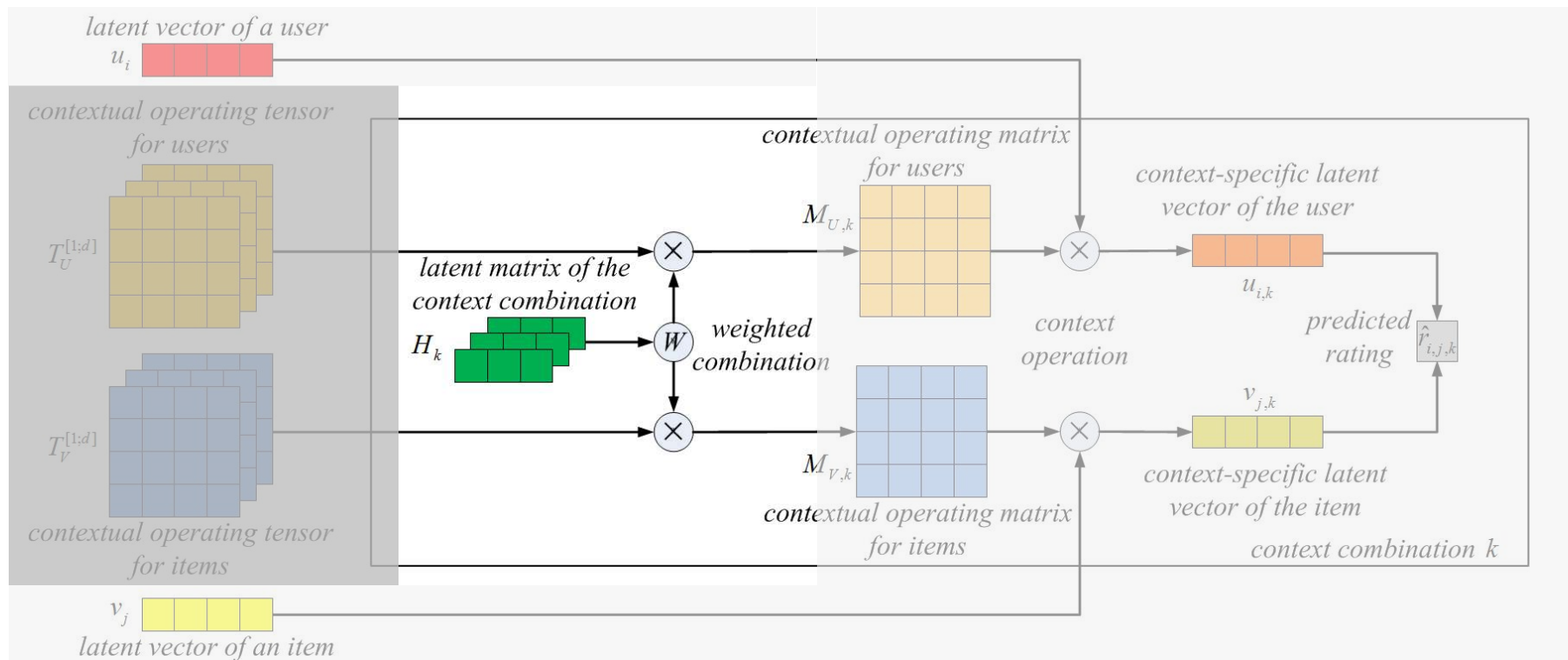
$$v_{j,k} = M_{V,k} v_j$$





## Combination of Contexts:

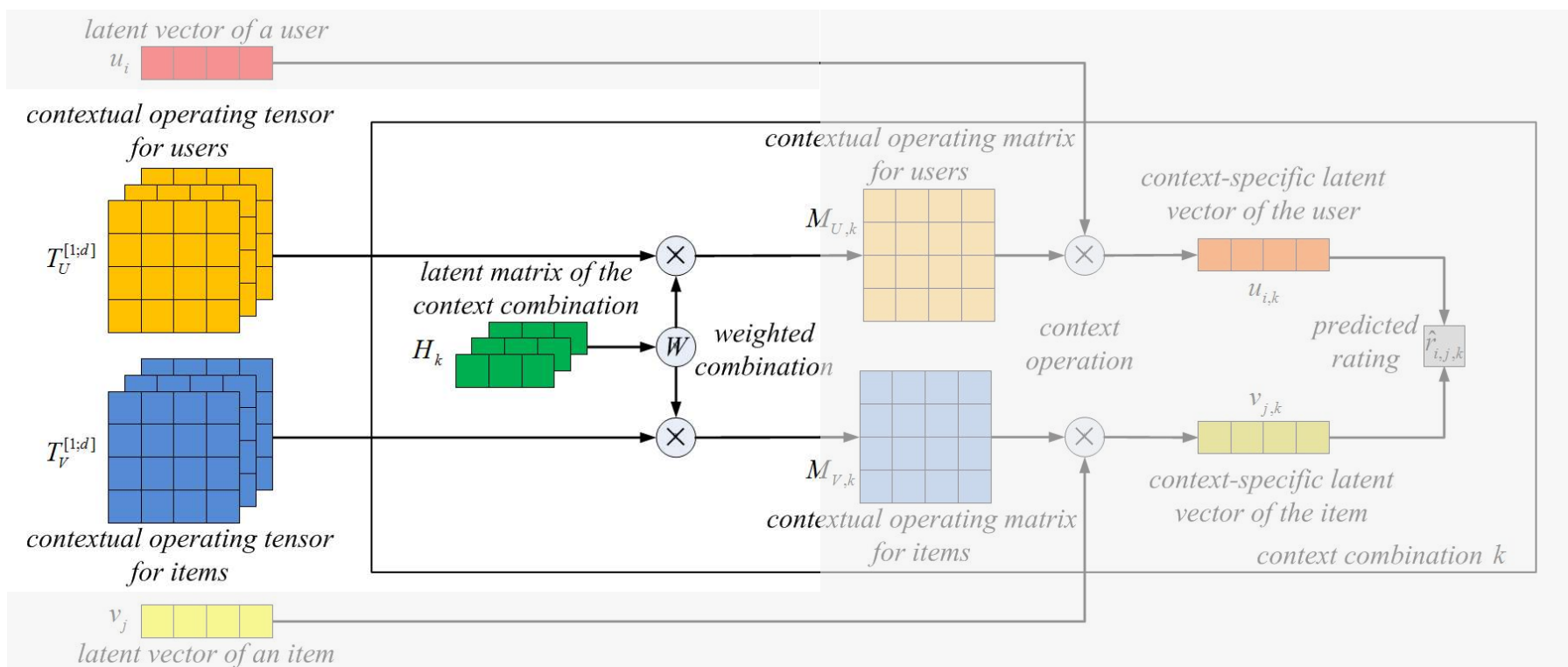
$$a_k = H_k W$$



## Contextual Operating Tensor:

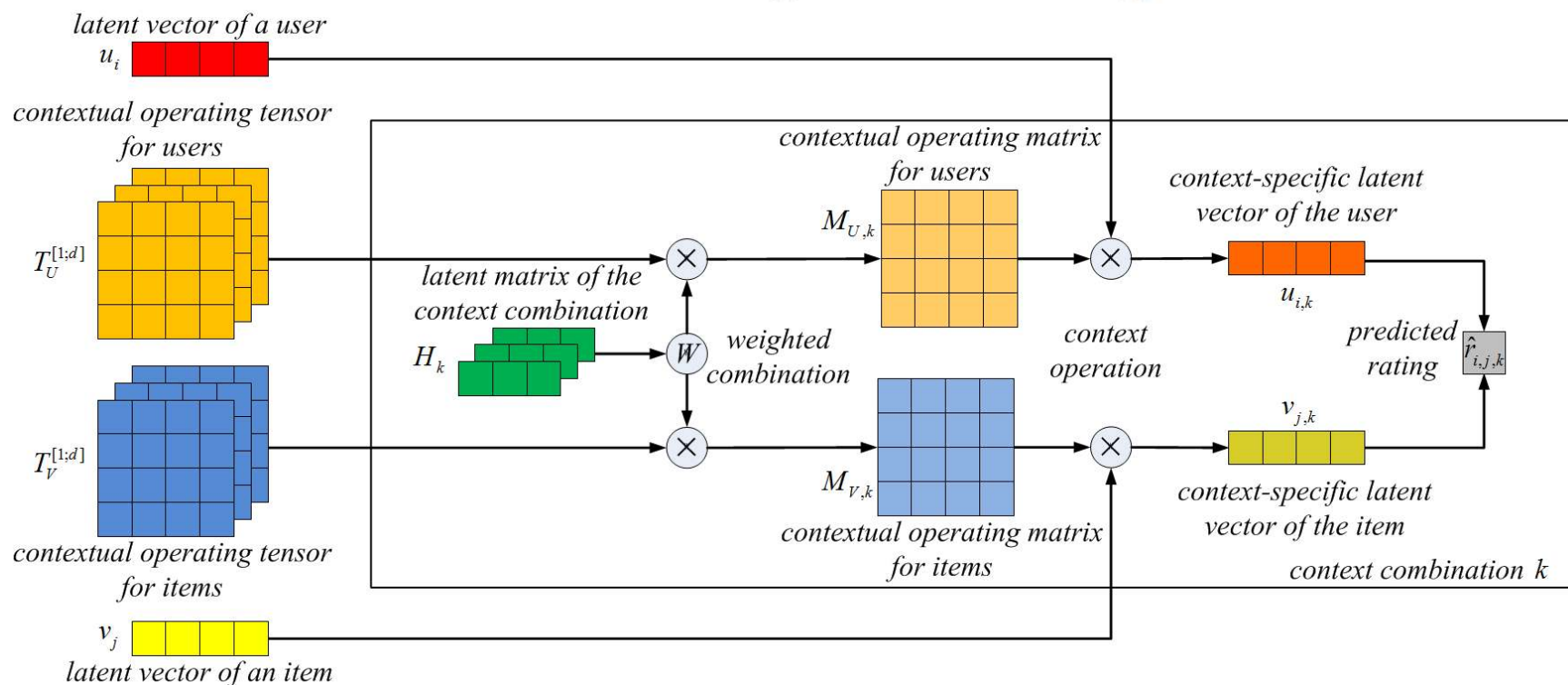
$$M_{U,k} = a_k^T T_U^{[1:d]}$$

$$M_{V,k} = a_k^T T_V^{[1:d]}$$



## Overall Function :

$$\hat{r}_{i,j,k} = \omega_0 + \omega_i + \omega_j + \sum_{m=1}^n \omega_{m,k} + \underbrace{\left[ (H_k W)^T T_U^{[1:d]} u_i \right]}_{u_{i,k}}^T \underbrace{\left[ (H_k W)^T T_V^{[1:d]} v_j \right]}_{v_{j,k}}$$



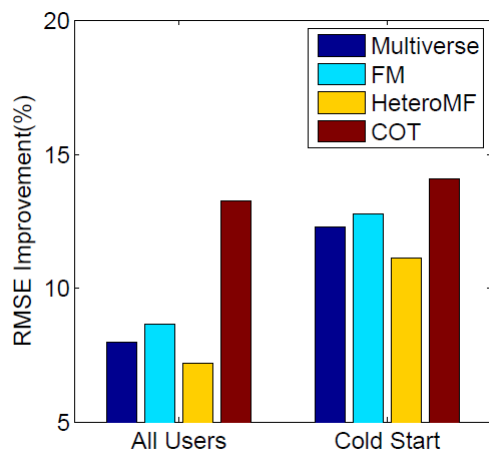
compared methods	metrics	dataset splitting
SVD++ Multiverse recommendation FM HeteroMF <sup>1</sup>	RMSE MAE	All Users Cold Start

dataset	#contexts	contexts
Food dataset	2	<i>virtuality, hunger</i>
Adom dataset	5	<i>when, where, companion, release, recommendation</i>
Movielens-1M	2	<i>hour in a day, day in a week</i>

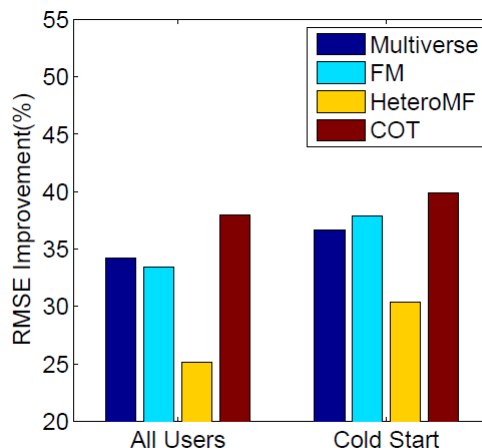
(1) Jamali and Lakshmanan, Heteromf: recommendation in heterogeneous information networks using context dependent factor models.

# Performance Comparison

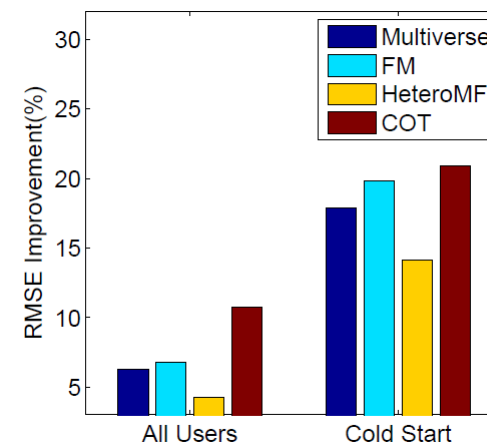
	Food Dataset				Adom Dataset				Movielens-1M			
	All Users		Cold Start		All Users		Cold Start		All Users		Cold Start	
	RMSE	MAE	RMSE	MAE	RMSE	MAE	RMSE	MAE	RMSE	MAE	RMSE	MAE
SVD++	1.155	0.948	1.278	1.086	2.782	2.093	3.421	2.436	0.942	0.721	1.248	0.956
Multiverse	1.063	0.841	1.121	0.921	1.833	1.383	2.168	1.556	0.883	0.669	1.025	0.771
FM	1.055	0.845	1.115	0.918	1.852	1.446	2.125	1.563	0.878	0.672	1.001	0.766
HeteroMF	1.072	0.862	1.136	0.932	2.084	1.552	2.384	1.782	0.902	0.686	1.072	0.792
COT	<b>1.002</b>	<b>0.792</b>	<b>1.098</b>	<b>0.898</b>	<b>1.726</b>	<b>1.367</b>	<b>2.056</b>	<b>1.518</b>	<b>0.841</b>	<b>0.645</b>	<b>0.987</b>	<b>0.759</b>



Food Dataset

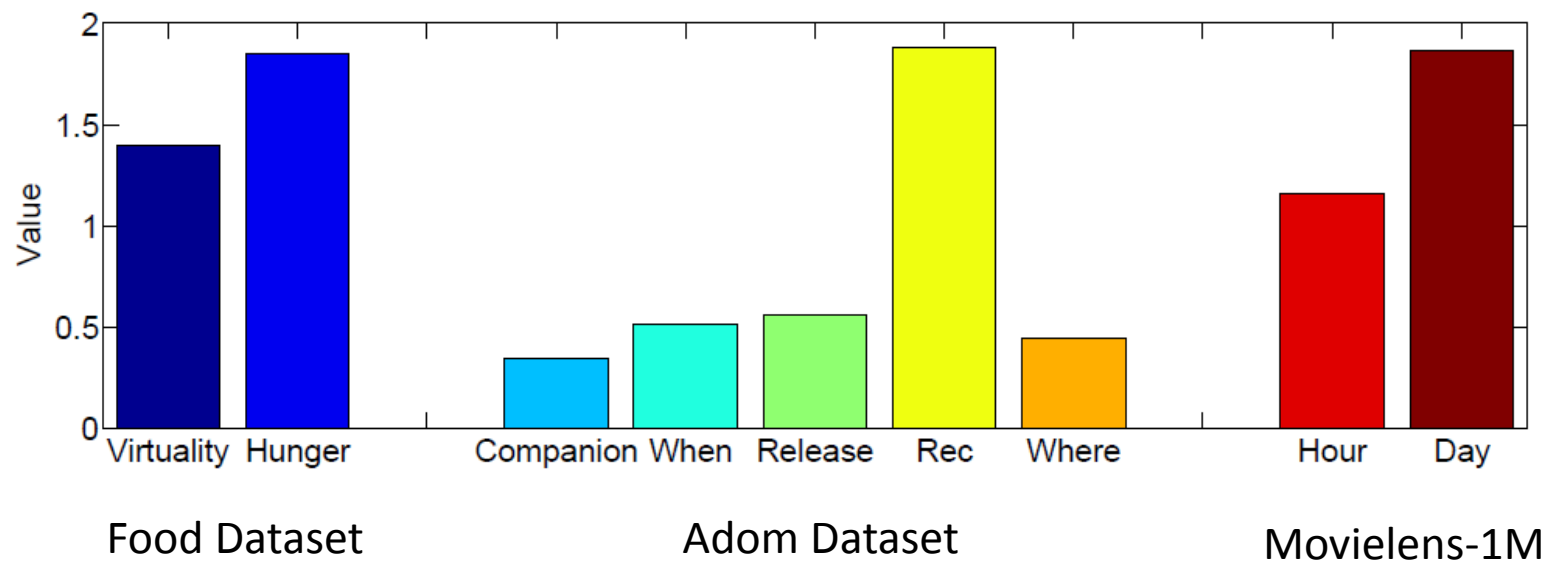


Adom Dataset



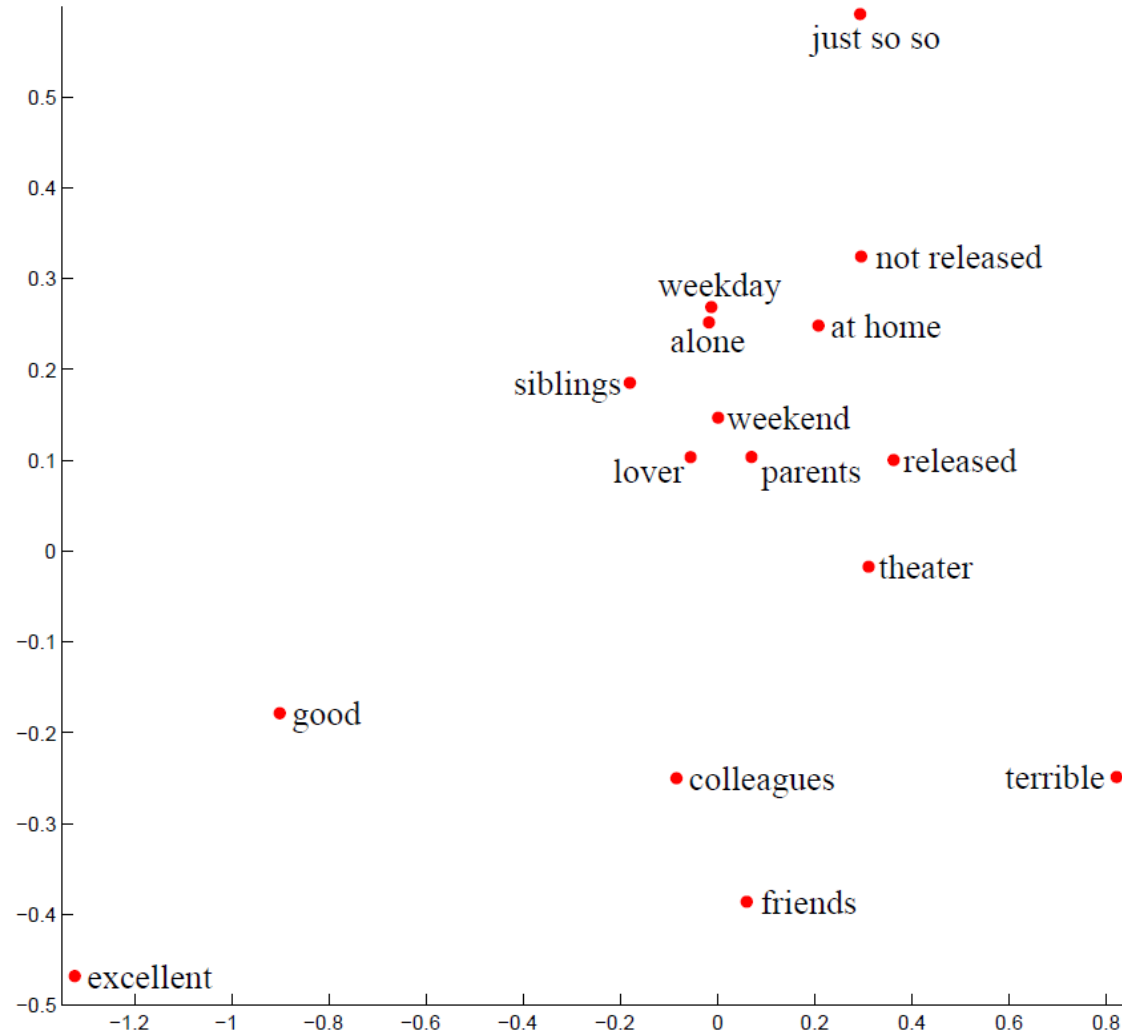
Movielens-1M

# Weights of Different Contexts



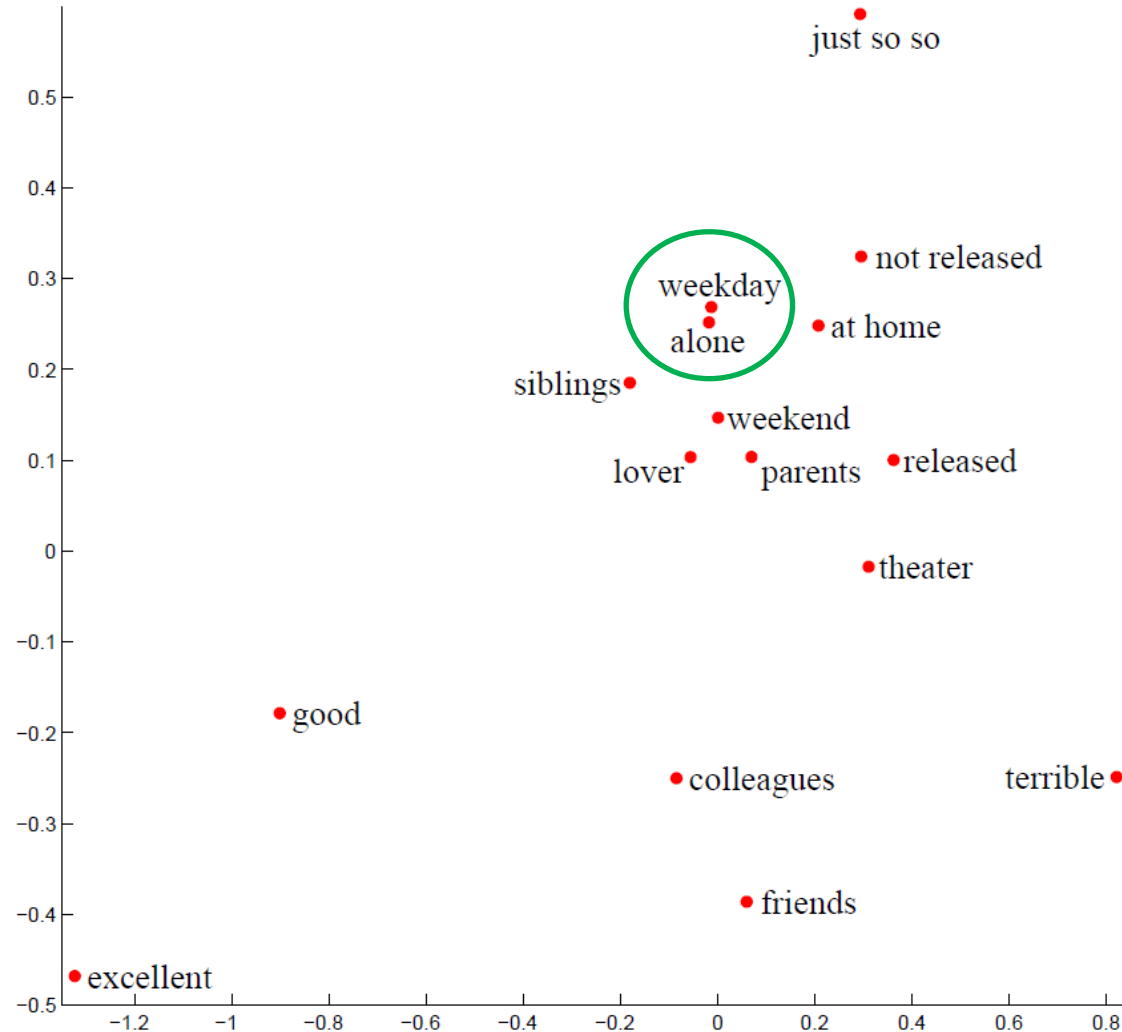
# Distributed Representation of Contexts

We use PCA and project the distributed representations of contexts in the Adom dataset into a two-dimensional space.



# Distributed Representation of Contexts

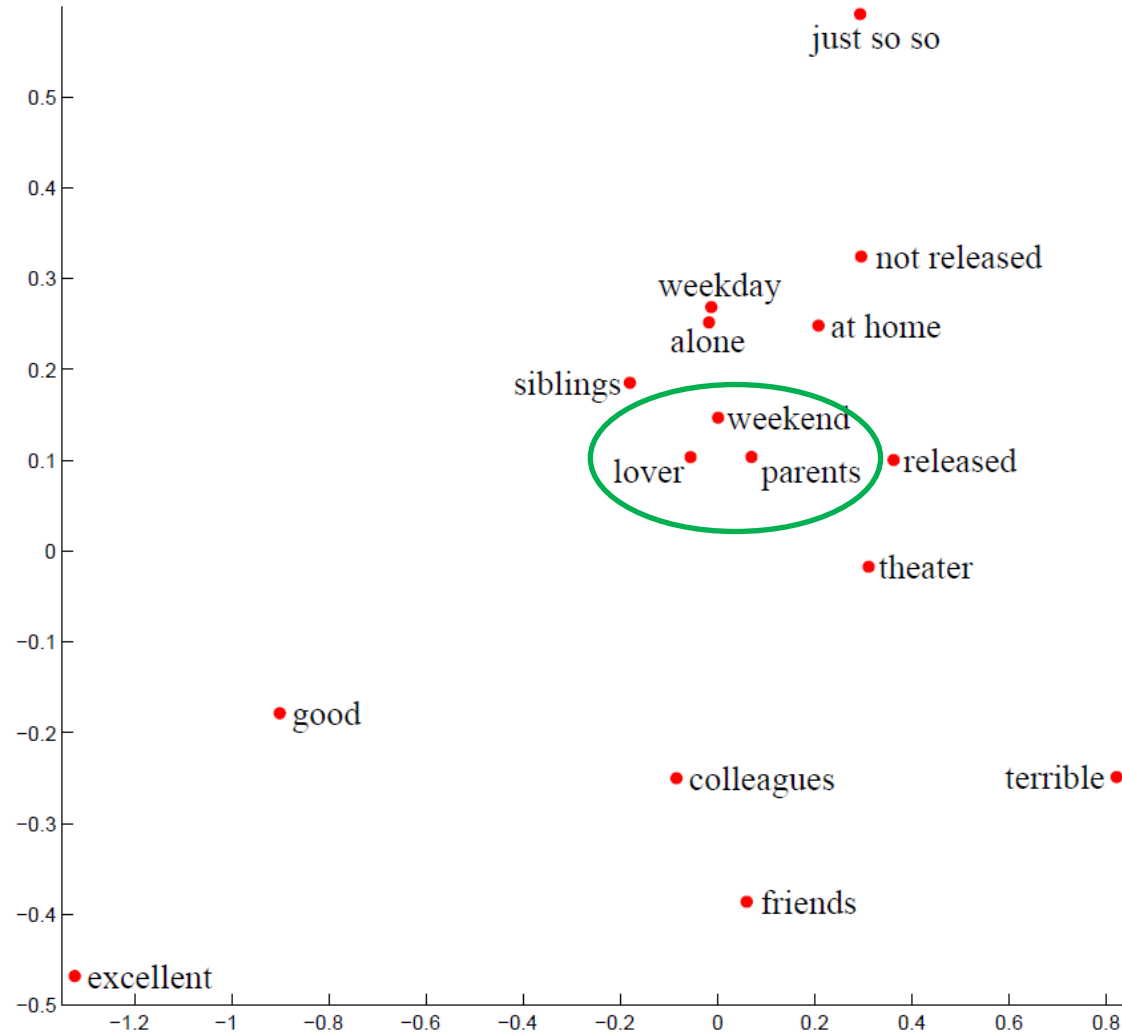
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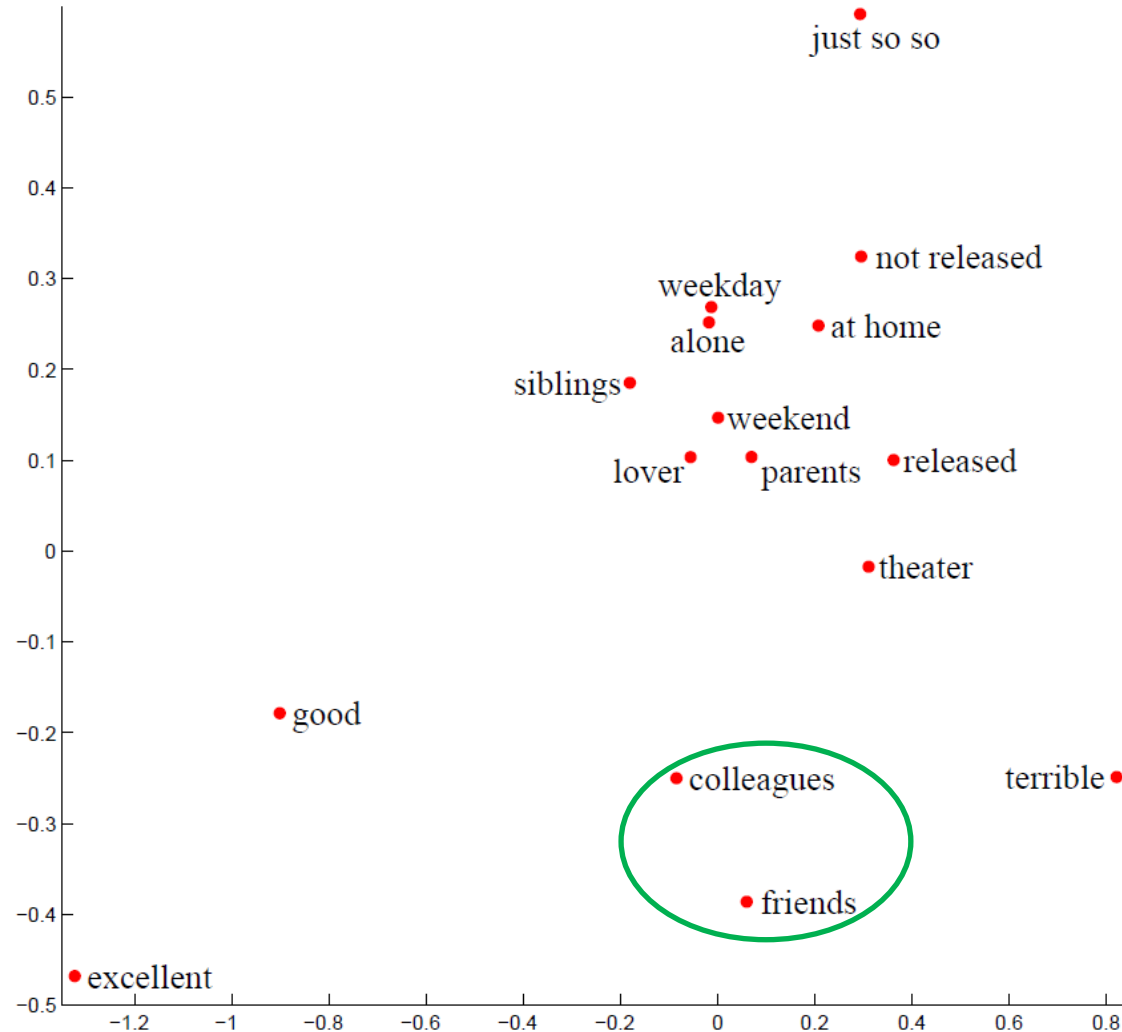
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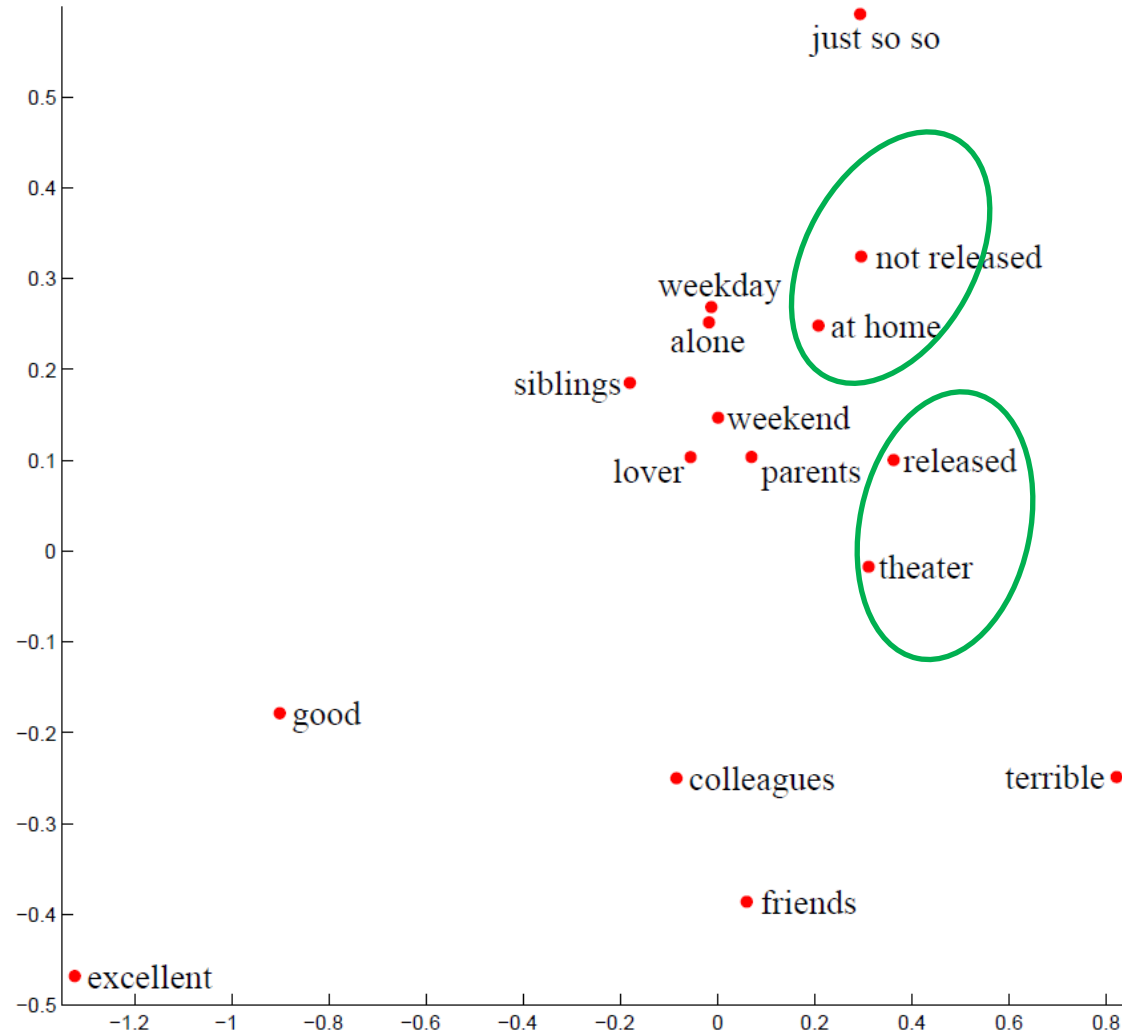
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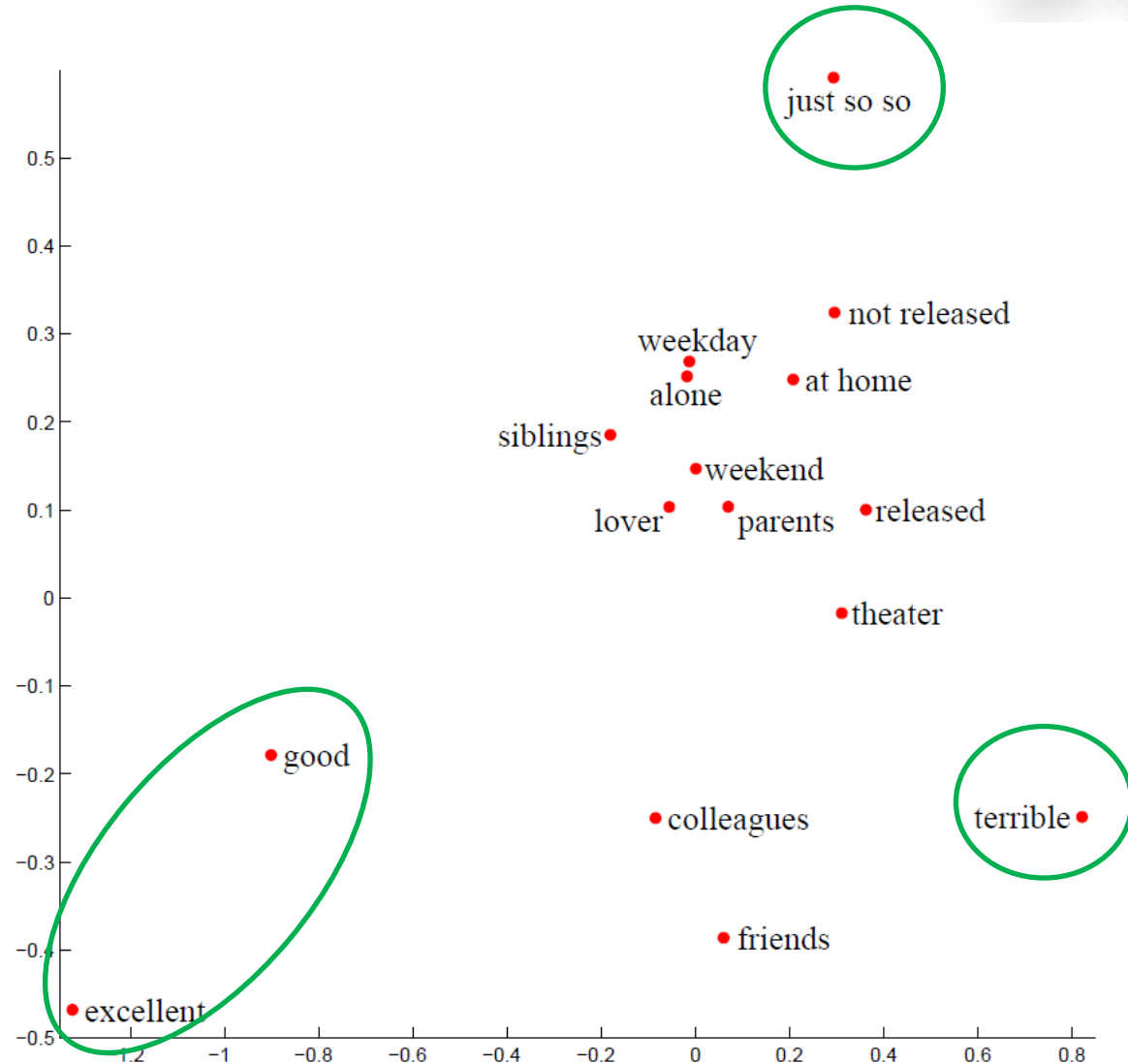
# Distributed Representation of Contexts

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# Distributed Representation of Contexts

We use PCA and project the distributed representations of contexts in the Adom dataset into a two-dimensional space.



- Model the contextual information as the **semantic operation** on entities
- Use contextual operating **tensor** to capture the **common** semantic effects of contexts, and latent **vectors** to capture the **specific** properties of contexts.
- Generate the contextual operating **matrix** from contextual operating **tensor** and latent **vectors**.

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Thanks!

Q & A

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