FEMA: FLEXIBLE EVOLUTIONARY MULTI-FACETED ANALYSIS FOR DYNAMIC BEHAVIOR PATTERN DISCOVERY

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Behavior Analysis

Modeling

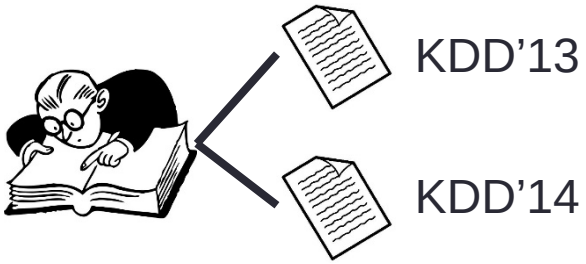
How to formulate human behavior?

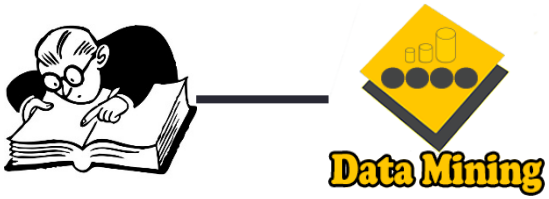
Pattern discovery

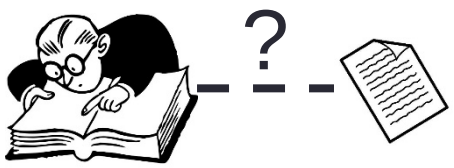
How to understand human behavior?

Prediction

What is the missing human behavior?







Our Goals

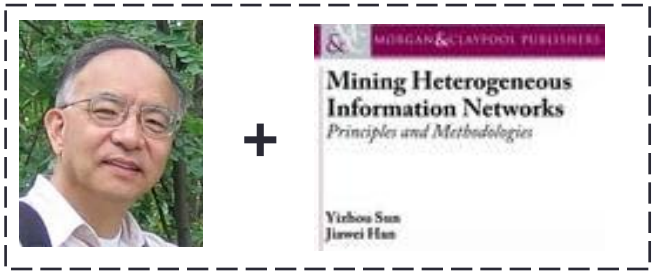
- Given: Behavioral data sequence
- Find: A general framework that fast and best fit the behavioral data

- Goals:
  - G1. Model the human behavior
  - G2. Understand the hidden patterns
  - G3. Predict the missing behavior

OUTLINE

Human Behavior

- Write a paper/book



- Post a photo on Facebook

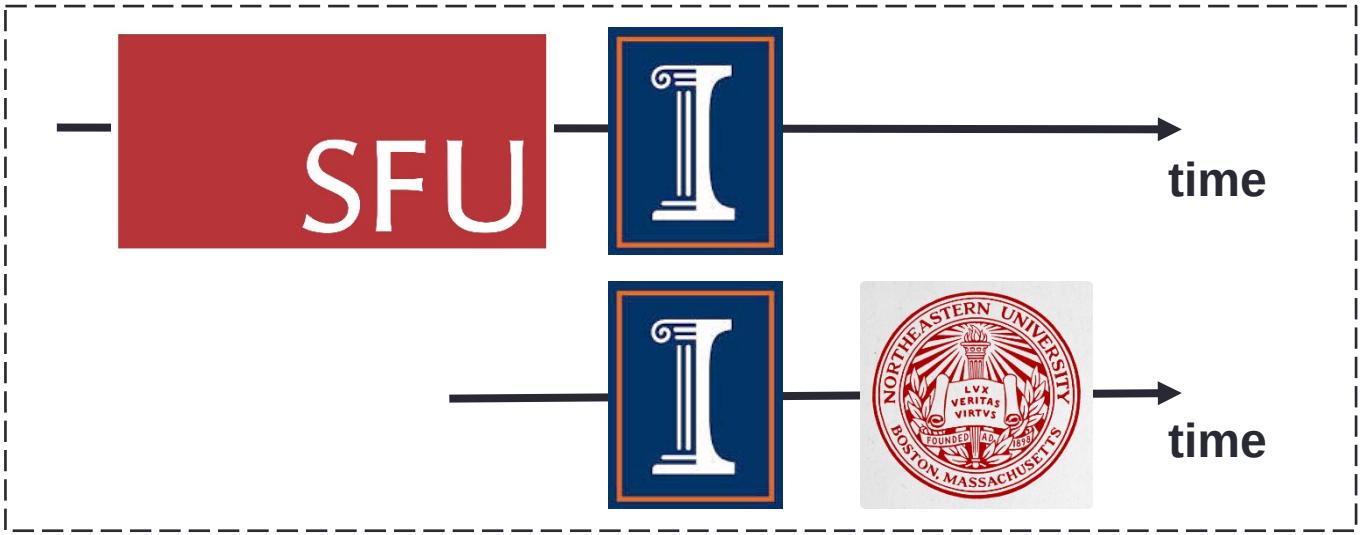
Human Behavior: Multi-faceted

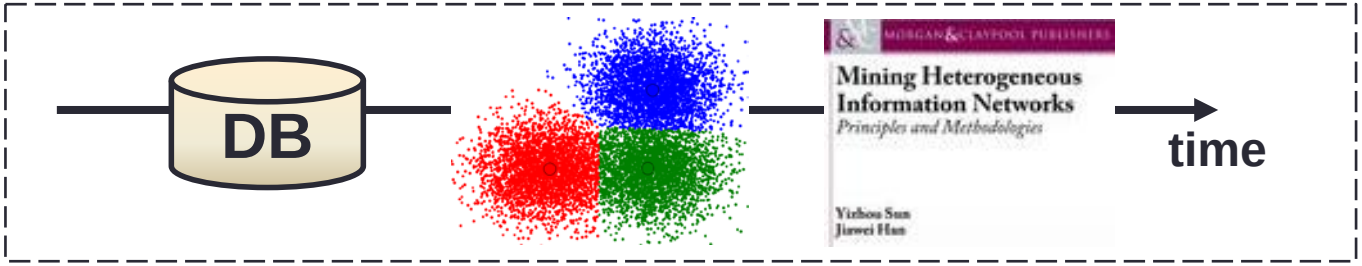
- Write a paper/book

- Post a photo on Facebook

Human Behavior: Dynamic

- Write a paper/book





Human Behavior: Dynamic

- Post Facebook messages

Human Behavior

- Multi-faceted
- Dynamic

- How to model human behavior?

OUTLINE

1. Background

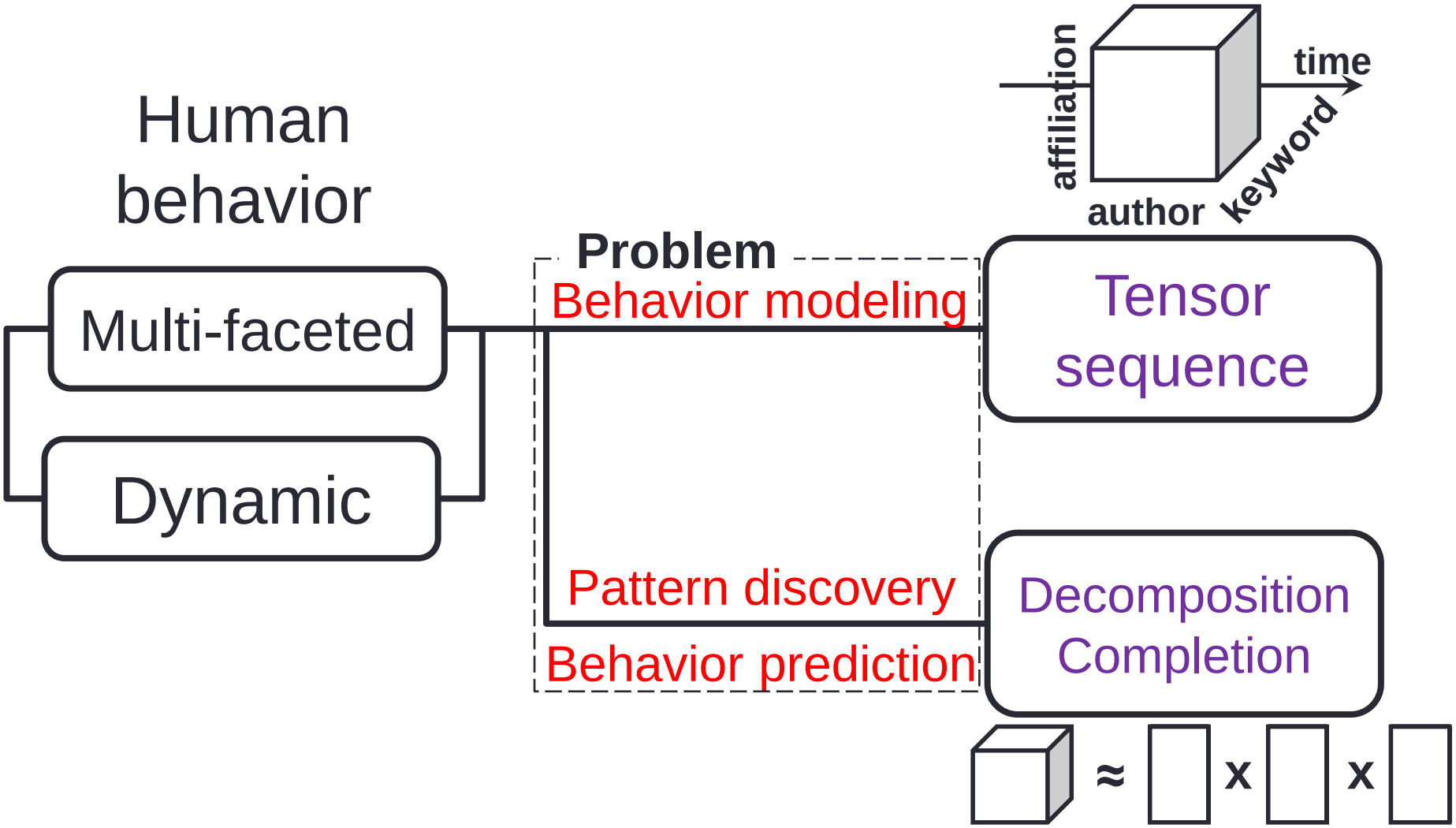
2. Model Formulation

3. The Framework

4. Experiments

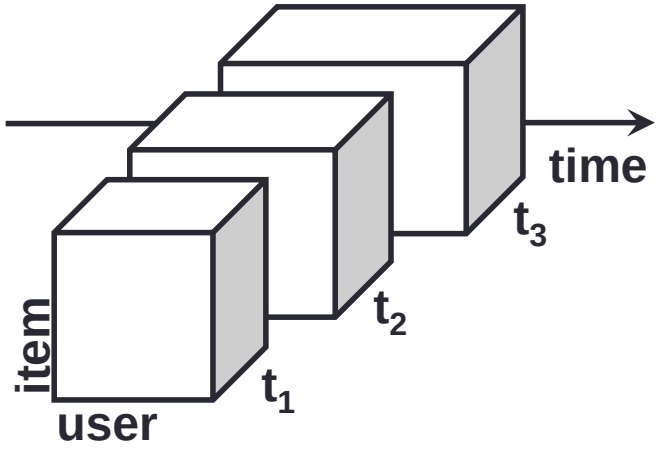
5. Visualization

Model Human Behavior



Challenges

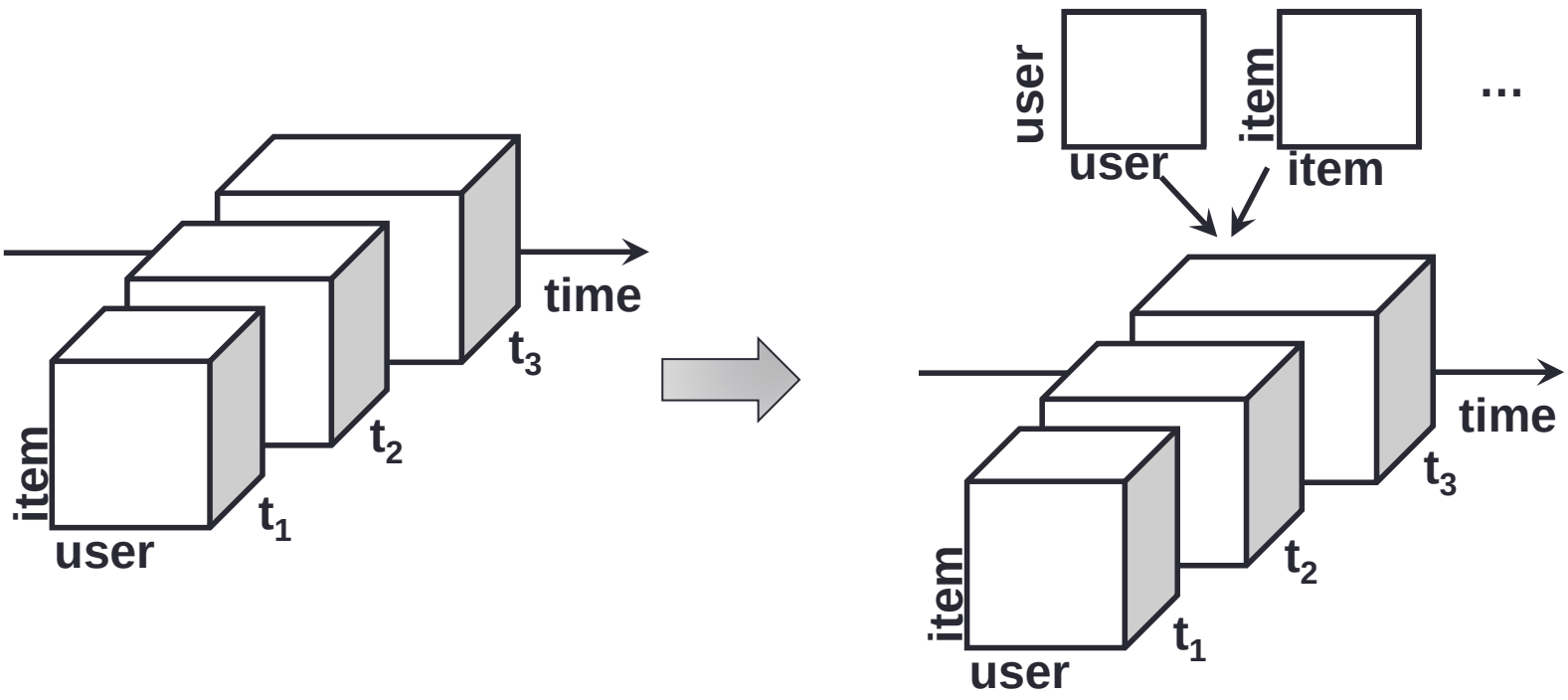
- High sparsity
  - High-order tensors



- High complexity
  - Long sequence of tensors
  - Too slow if decomposing at each time

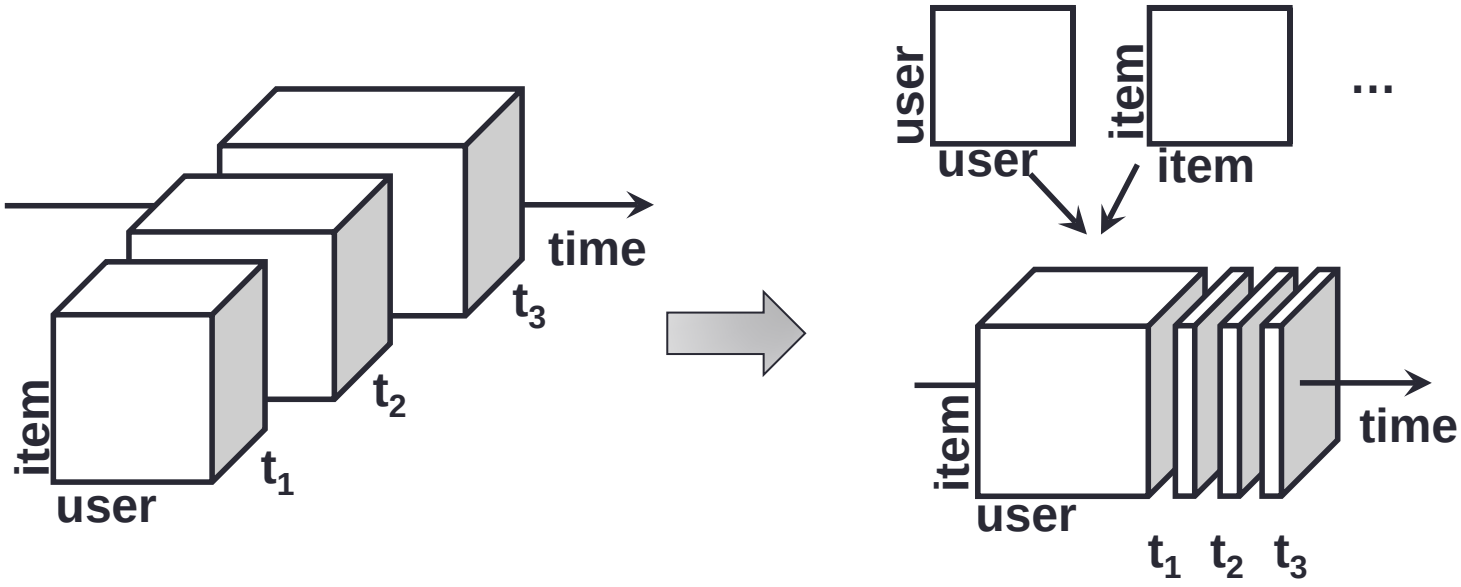
Idea

- High sparsity
  - **Auxiliary knowledge as regularizations**



Idea

- High complexity
  - **Update projection matrices with new coming piece of data**



OUTLINE

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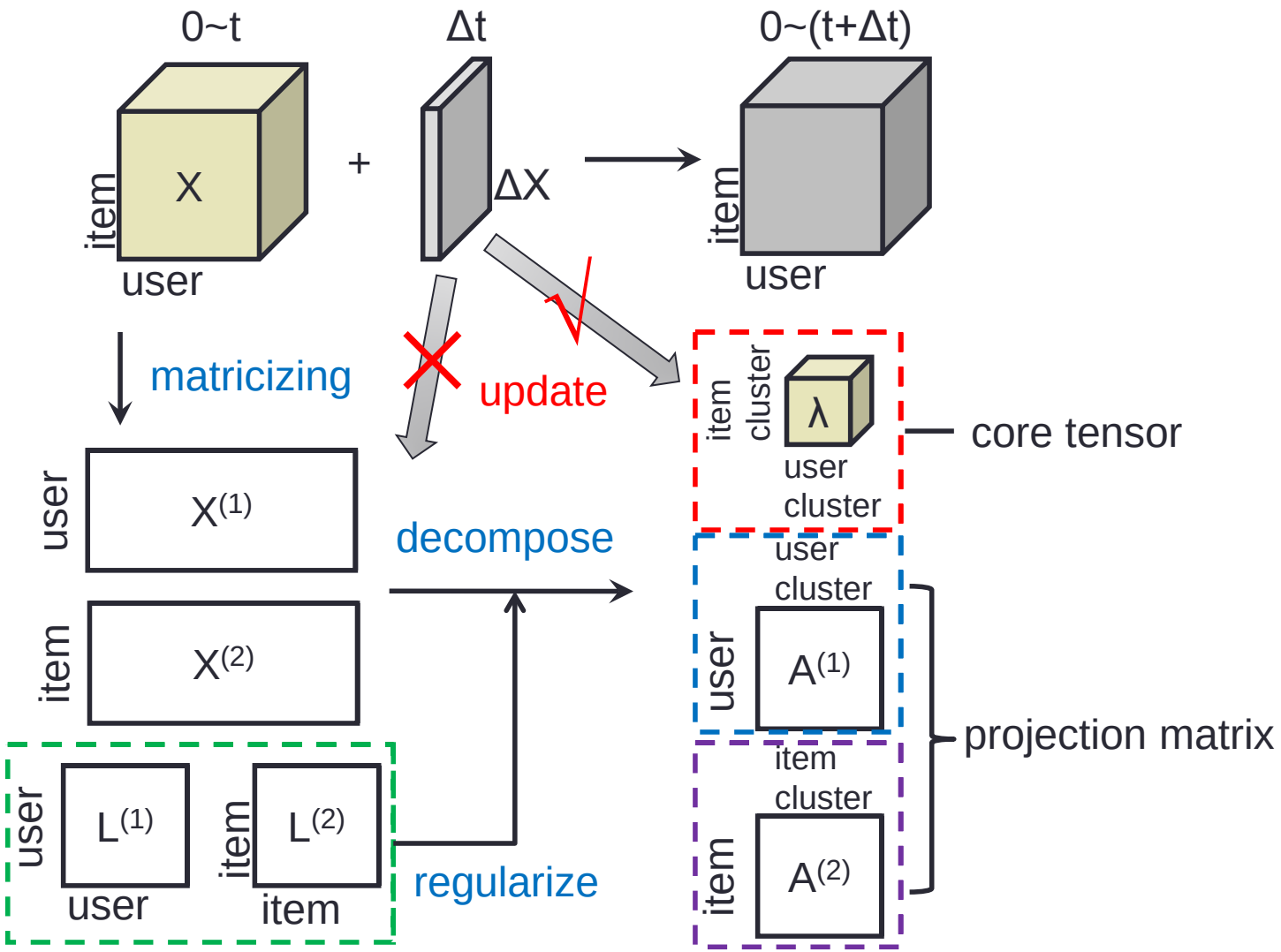
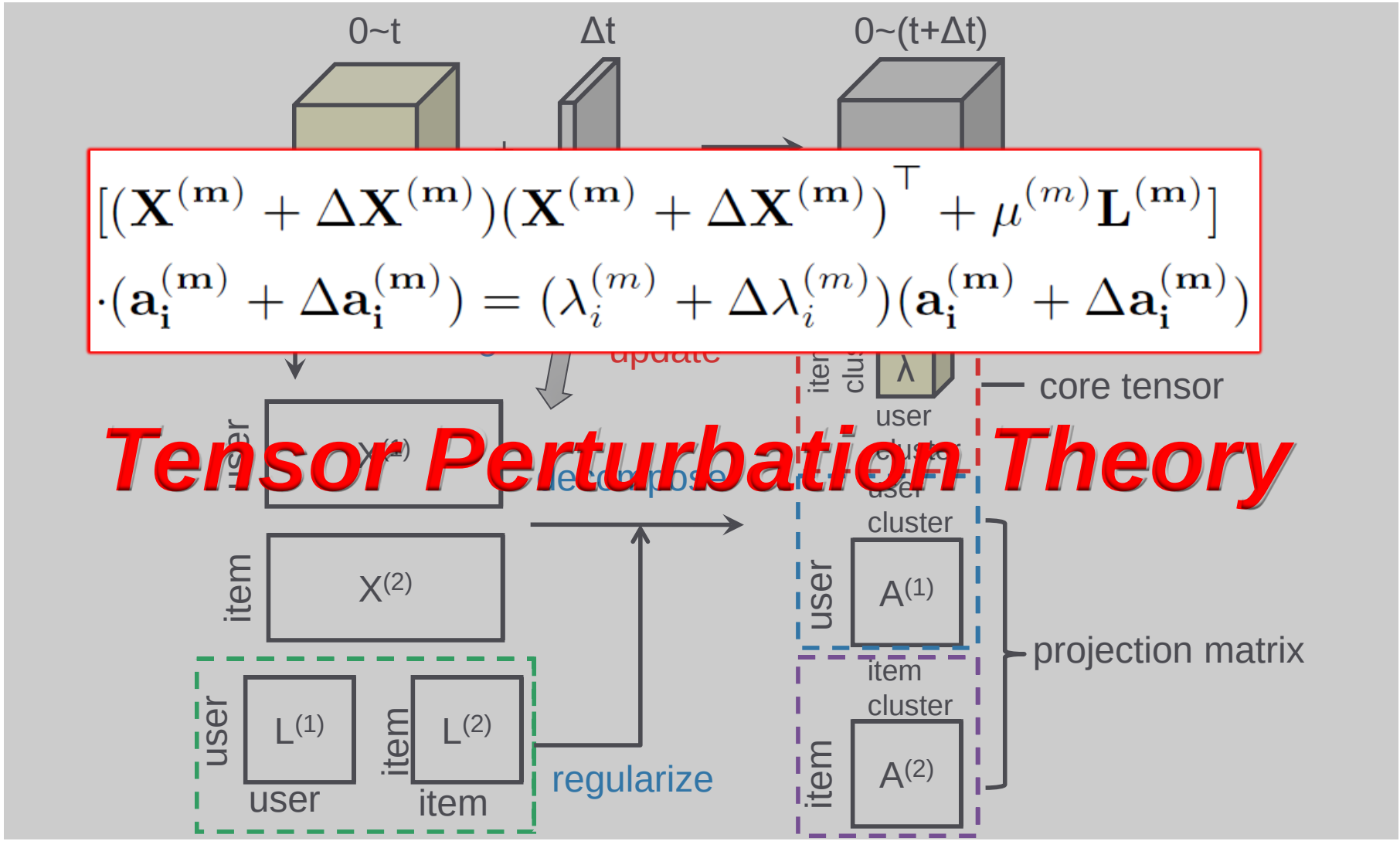
FEMA: Flexible Evolutionary Multi-faceted Analysis



FEMA: Flexible Evolutionary Multi-faceted Analysis



FEMA Algorithm

Approximation **Bound Guarantee**

Require: $\mathcal{X}_t, \Delta\mathcal{X}_t, \mathbf{A_t^{(m)}}|_{m=1}^{M}, \lambda_t^{(m)}|_{m=1}^{M}$

for $m = 1, \ldots, M$ **do**

for $i = 1, \ldots, r^{(m)}$ **do**

Compute $\Delta\lambda_{t,i}^{(m)}$ using

$$\Delta\lambda_i^{(m)} = \mathbf{a_i^{(m)\top}}(\mathbf{X^{(m)}}\Delta\mathbf{X^{(m)\top}} + \Delta\mathbf{X^{(m)}}\mathbf{X^{(m)\top}})\mathbf{a_i^{(m)}}$$

and compute

$$\lambda_{t+1,i}^{(m)} = \lambda_{t,i}^{(m)} + \Delta\lambda_{t,i}^{(m)};$$

Compute $\Delta\mathbf{a_{t,i}^{(m)}}$ using

$$\Delta\mathbf{a_i^{(m)}} = \sum_{j\neq i} \frac{\mathbf{a_j^{(m)\top}}(\mathbf{X^{(m)}}\Delta\mathbf{X^{(m)\top}} + \Delta\mathbf{X^{(m)}}\mathbf{X^{(m)\top}})\mathbf{a_i^{(m)}}}{\lambda_i^{(m)} - \lambda_j^{(m)}}\mathbf{a_j^{(m)}}$$

and compute

$\mathbf{a_{t+1,i}^{(m)}} = \mathbf{a_{t,i}^{(m)}} + \Delta\mathbf{a_{t,i}^{(m)}}$ and $\mathbf{A_{t+1}^{(m)}} = \{\mathbf{a_{t+1,i}^{(m)}}\}$;

end for

end for

$\mathcal{Y}_{t+1} = (\mathcal{X}_t + \Delta\mathcal{X}_t)\prod_{m=1}^{M} \times_{(m)} \mathbf{A_{t+1}^{(m)T}}$;

return $\mathbf{A_{t+1}^{(m)}}|_{m=1}^{M}, \lambda_{t+1}^{(m)}|_{m=1}^{M}, \mathcal{Y}_{t+1}$

core tensor

$$|\Delta\lambda_i^{(m)}| \leq 2(\lambda^{\max}_{\mathbf{X^{(m)\top}X^{(m)}}})^{\frac{1}{2}}\|\Delta\mathbf{X^{(m)}}\|_2$$

projection matrix

$$|\Delta\mathbf{a_i^{(m)}}| \leq 2\|\Delta\mathbf{X^{(m)}}\|_2 \sum_{j\neq i} \frac{(\lambda^{\max}_{\mathbf{X^{(m)\top}X^{(m)}}})^{\frac{1}{2}}}{|\lambda_i^{(m)} - \lambda_j^{(m)}|}$$

OUTLINE

1. Background
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3. The Framework
4. **Experiments**
5. Visualization

Experiments: Test Behavior Prediction

- Data sets
- Leveraging multi-faceted information
- Leveraging flexible regularizations
- Efficiency, loss and parameters

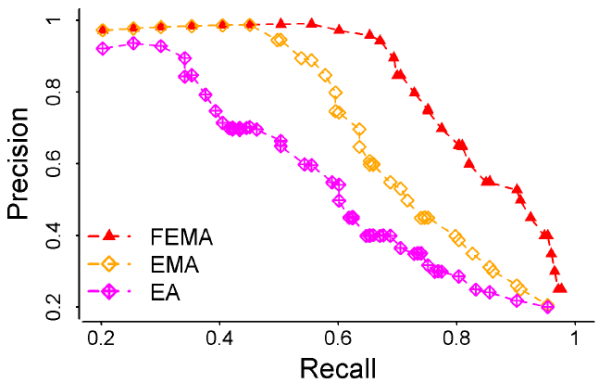
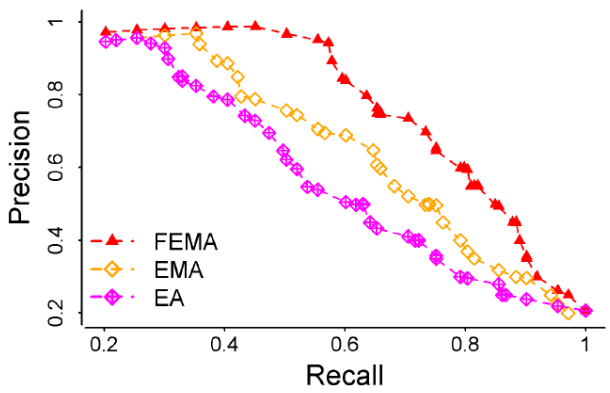
Data Sets

- Microsoft Academic Search
  - Subset of top 100 experts from query “data mining”
  - Paper: <author, affiliation and keyword>
  - Regularization: co-authorship <author, author>
  - 7,777 x 651 x 4,566 x 32 years: 171,519 tuples
- Tencent Weibo
  - 43 days: Nov. 9, 2011 to Dec. 20, 2011
  - Tweet: **<user-who-@, @-ed-user, word>**
  - Regularization: social relation <user, user>
  - 6,200 x 1,813 x 6,435 x 43 days: 519,624 tuples

Leveraging Multi-faceted Information

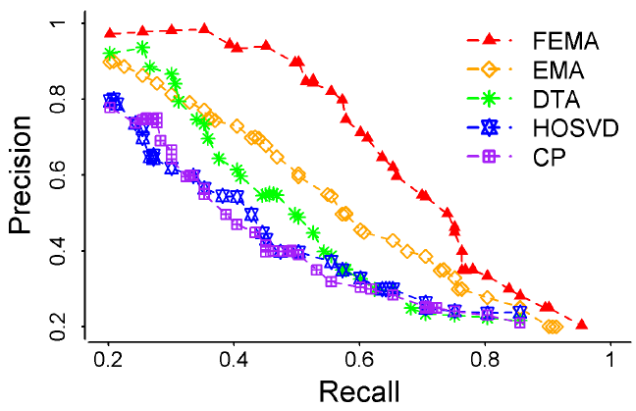
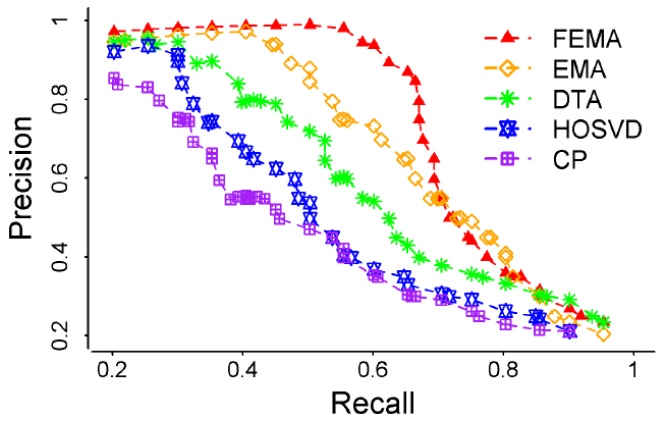
Predict "Who"-"What keyword"
FEMA uses "Where" (affiliation).

Predict "Who"-"@Whom"
FEMA use "What" (tweet word).

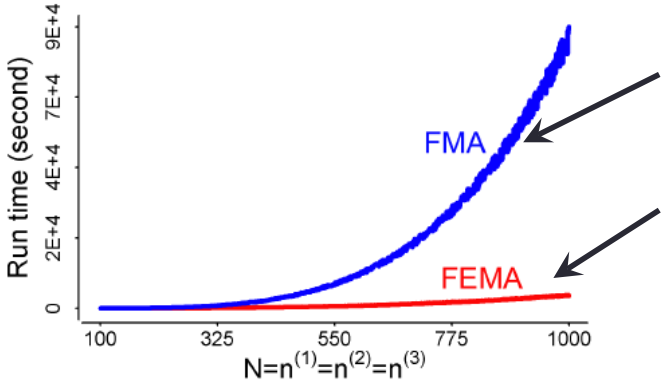
	Microsoft Academic Search		Tencent Weibo	
	MAE	RMSE	MAE	RMSE
FEMA X L	**0.735**	**0.944**	**0.894**	**1.312**
EMA X	0.794	1.130	0.932	1.556
EA X	0.979	1.364	1.120	1.873
Precision vs Recall				

Leveraging Flexible Regularizations

"Who"-"Where"-"What keyword"? **"Who"-"@Whom"-"What"?**

	Microsoft Academic Search		Tencent Weibo	
	MAE	RMSE	MAE	RMSE
FEMA X L	**0.893**	**1.215**	**0.954**	**1.437**
EMA X	0.909	1.466	0.986	1.698
DTA [Sun et al.]	0.950	1.556	1.105	1.889
Precision vs Recall				

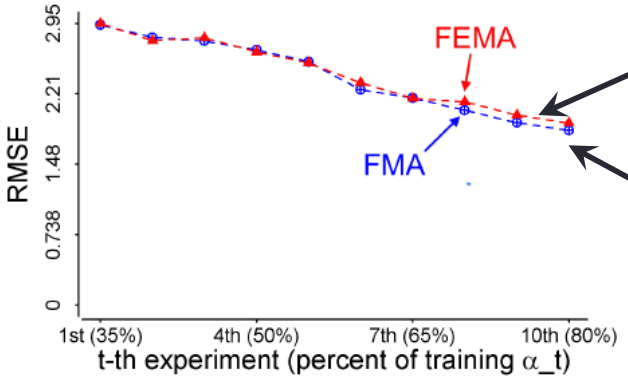
Efficiency, Loss and Parameters



Time vs Num. objects N

Re-decompose updated matrices

Evolutionary analysis: update λ and a with ΔX

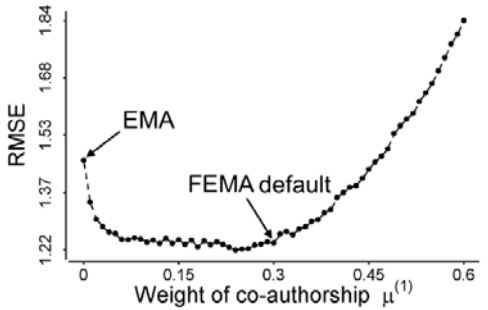


The loss is small.

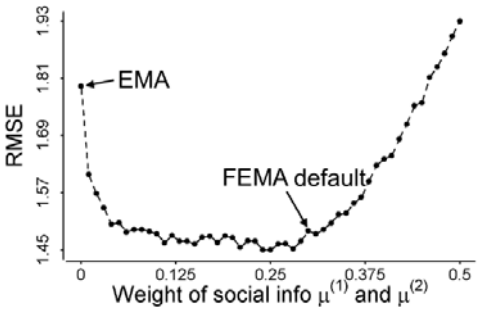
Evolutionary analysis: update λ and a with ΔX

Re-decompose updated matrices

Insensitive to regularization weight



(a) Academic data MAS



(b) Tweet data WEIBO

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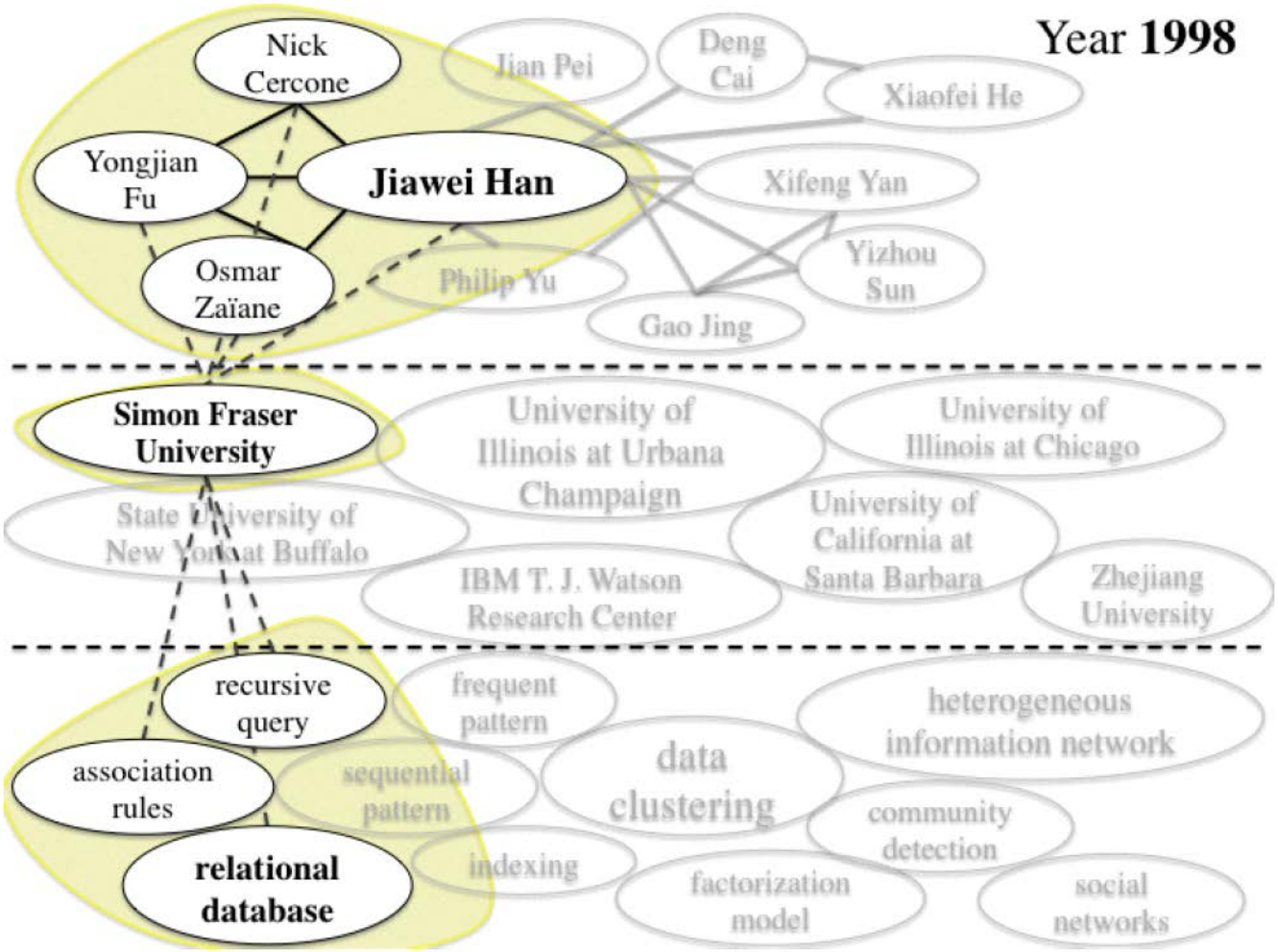
Visualization: Test Pattern Discovery

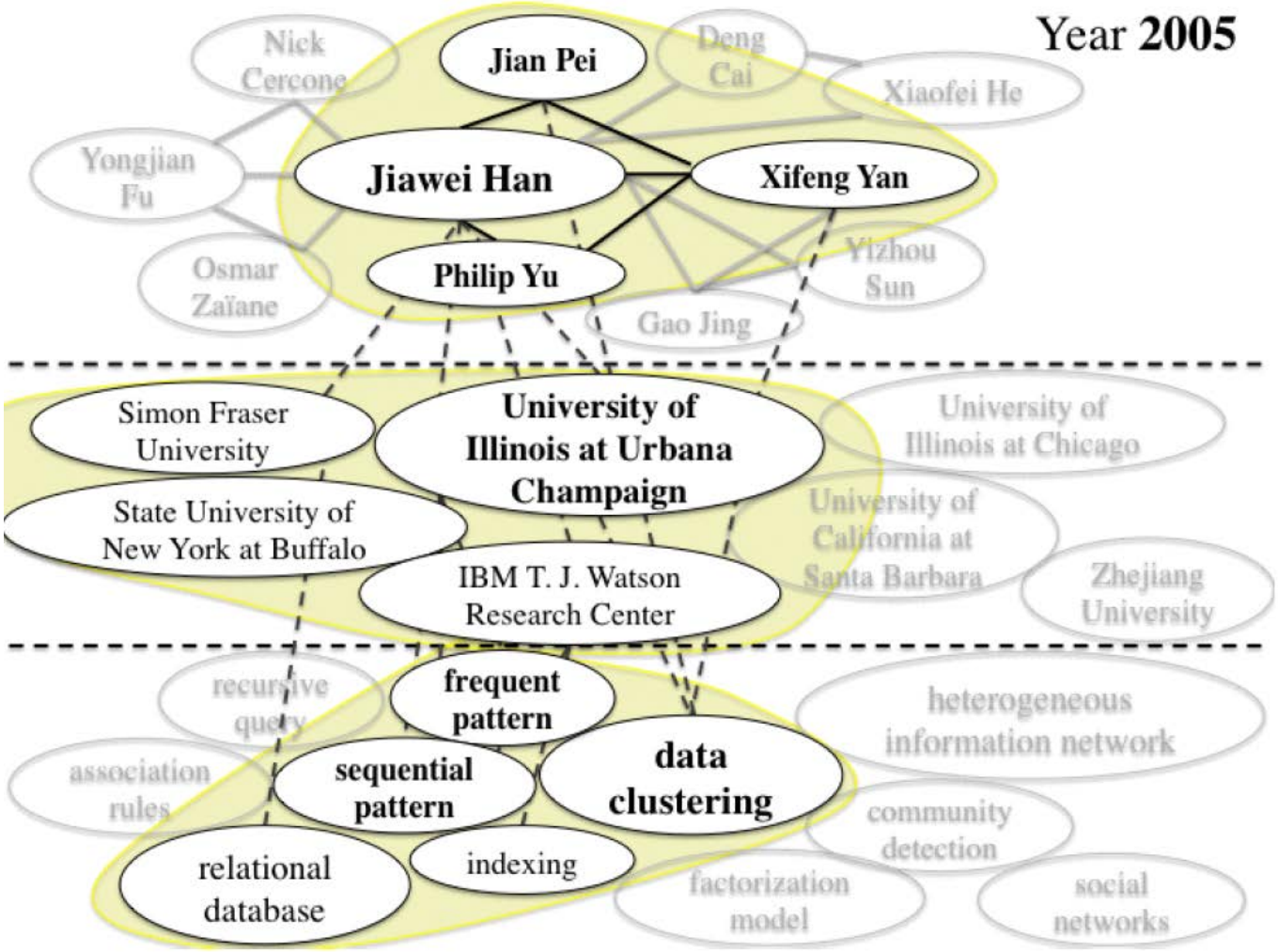
- Microsoft Academic Search
- Tencent Weibo (see our paper ☺)

- Behavior Patterns
  - Multi-faceted
  - Dynamic

Microsoft Academic Search



Microsoft Academic Search



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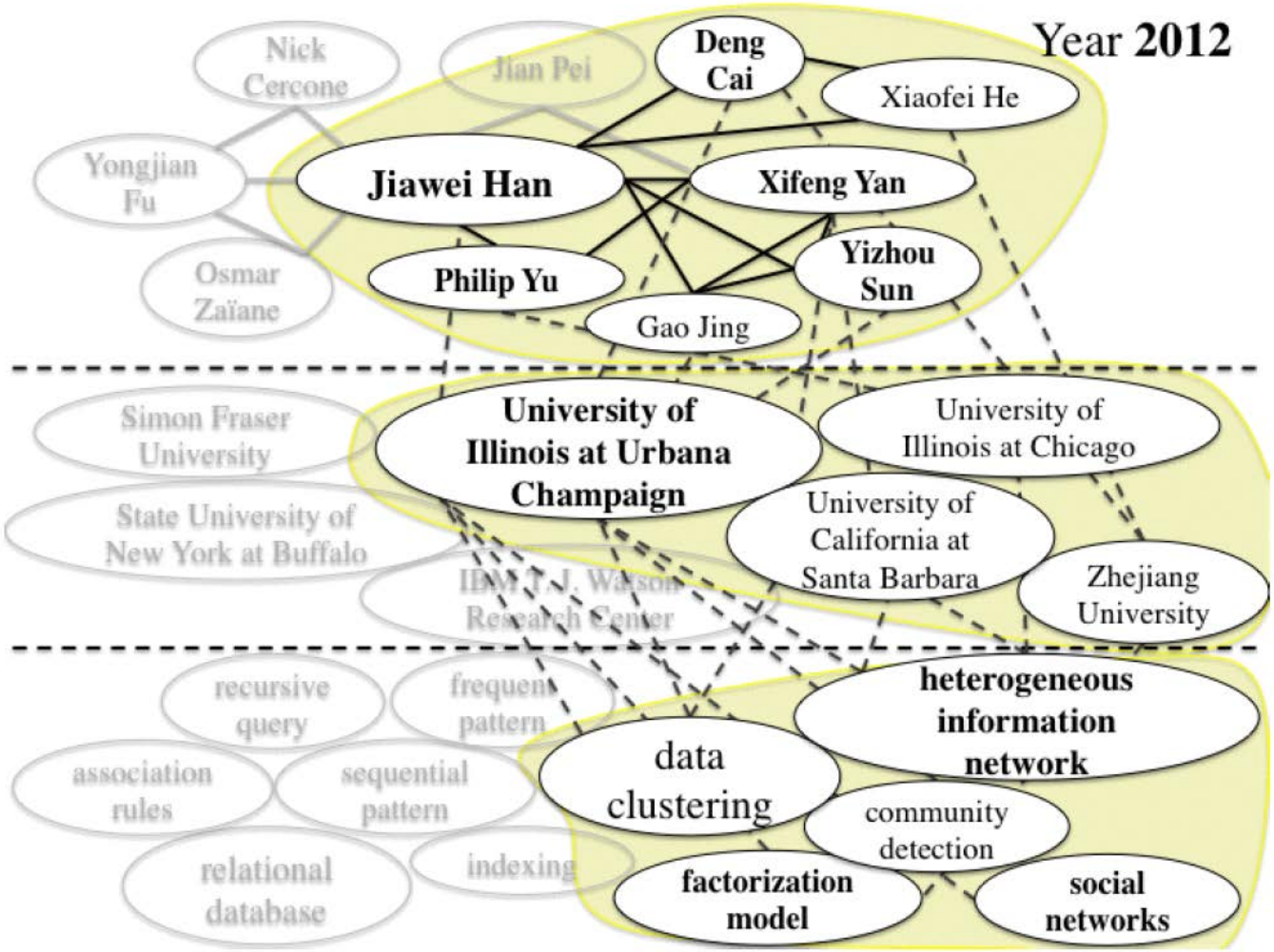
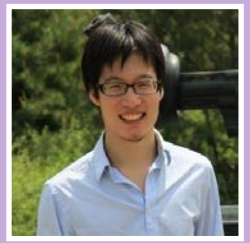


Conclusion

- **Human behavior**: multi-faceted and dynamic
- **Challenges**: high sparsity and high complexity
- **Solutions**: flexible regularizations & evolutionary analysis
- **FEMA**: approximation algorithm and bounds
- **Experiment**: behavior prediction
- **Visualization**: pattern discovery

Questions?





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