PRICAI 2022

合肥工業大學

APGKT: Exploiting Associative Path on Skills Graph for Knowledge Tracing

Haotian zhang, Chenyang Bu, Fei Liu*, Shuochen Liu, Yuhong Zhang, and Xuegang Hu*

Key Laboratory of Knowledge Engineering with Big Data (the Ministry of Education of China), School of Information Science and Computer Engineering, Hefei University of Technology

November 11th, 2022

Haotian Zhang

CONTENTS

01 Background

02 Proposed Model

03 Experiments

04 Conclusion

Background

Knowledge tracing (KT) is used to model students' dynamic mastery of skills based on their historical learning data and to infer their future answering performance.

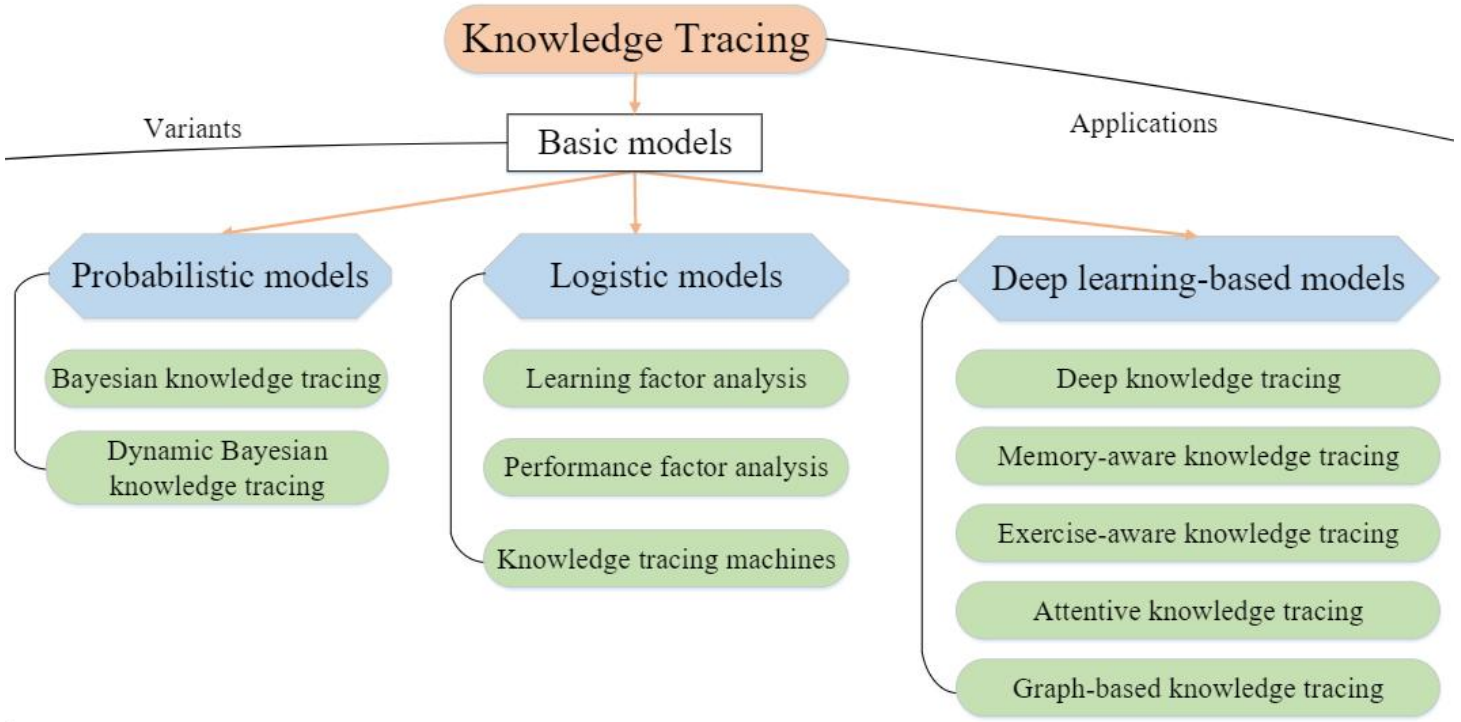


Fig. 1. An overview of KT models [1]

Students could obtain the correct answer only if they **mastered all the skills**.

use the **cognitive state of the skills** to predict a student's future answering performance.

[1] Q. Liu, S. Shen, Z. Huang, E. Chen, Y. Zheng, A survey of knowledge tracing,arXiv preprint arXiv:2105.15106 (2021).

Background

The question-answering process of students can be regarded as a **thinking process** that considers the following two problems. One problem is **which skills** are needed to answer the question, and the other is **how to use these skills** in order.

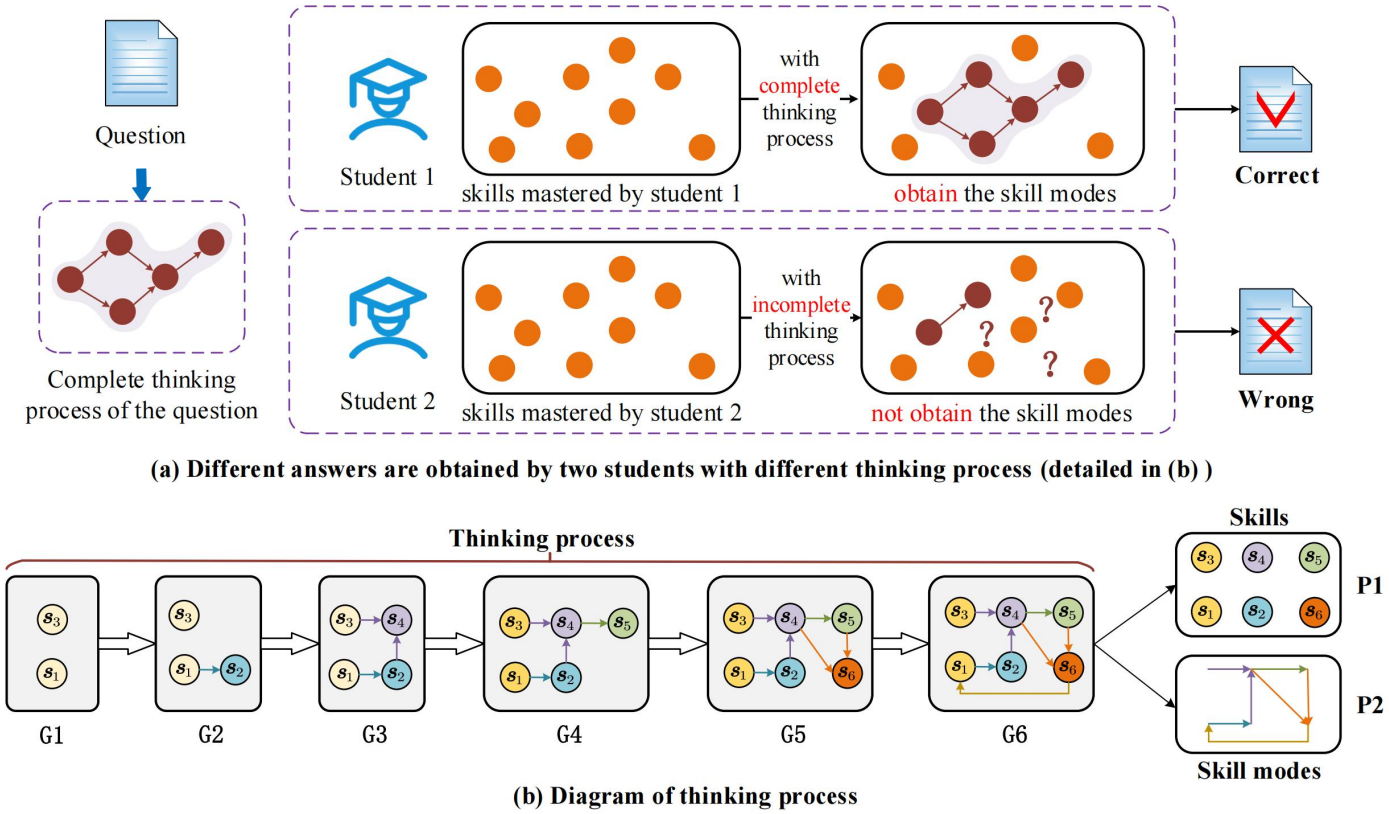


Fig. 2. Instance of students answering questions.

If a student wants to answer a question correctly, the student should not only master the set of skills involved in the question but should also think and obtain the associative path on the skills graph, the nodes in which are the skills to be used, and the path showing the order of using them. Here, the associative path is referred to as the **skill mode**.

Proposed Model

APGKT is proposed **considering skill modes** (e.g., P2 in Fig. 2(b)) to improve performance of KT.

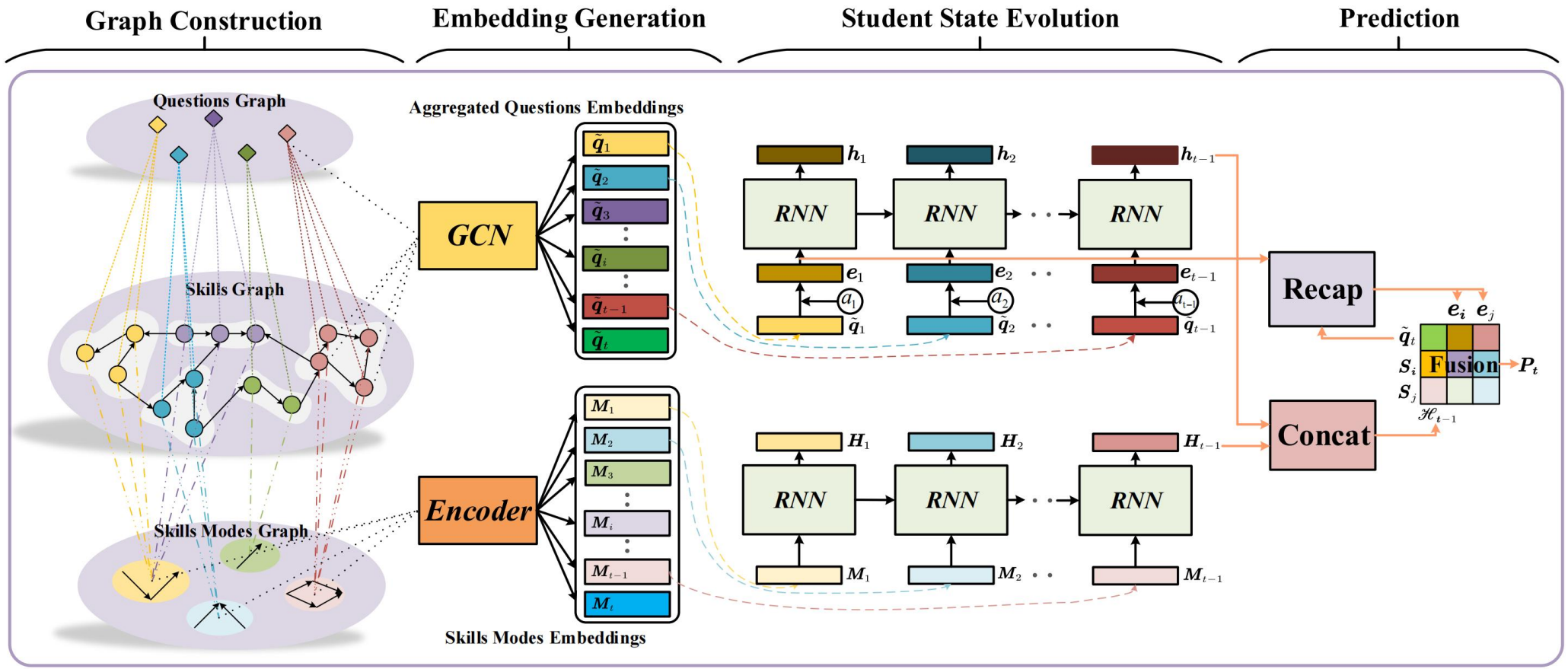


Fig. 3. Complete framework of the APGKT model.

Proposed Model

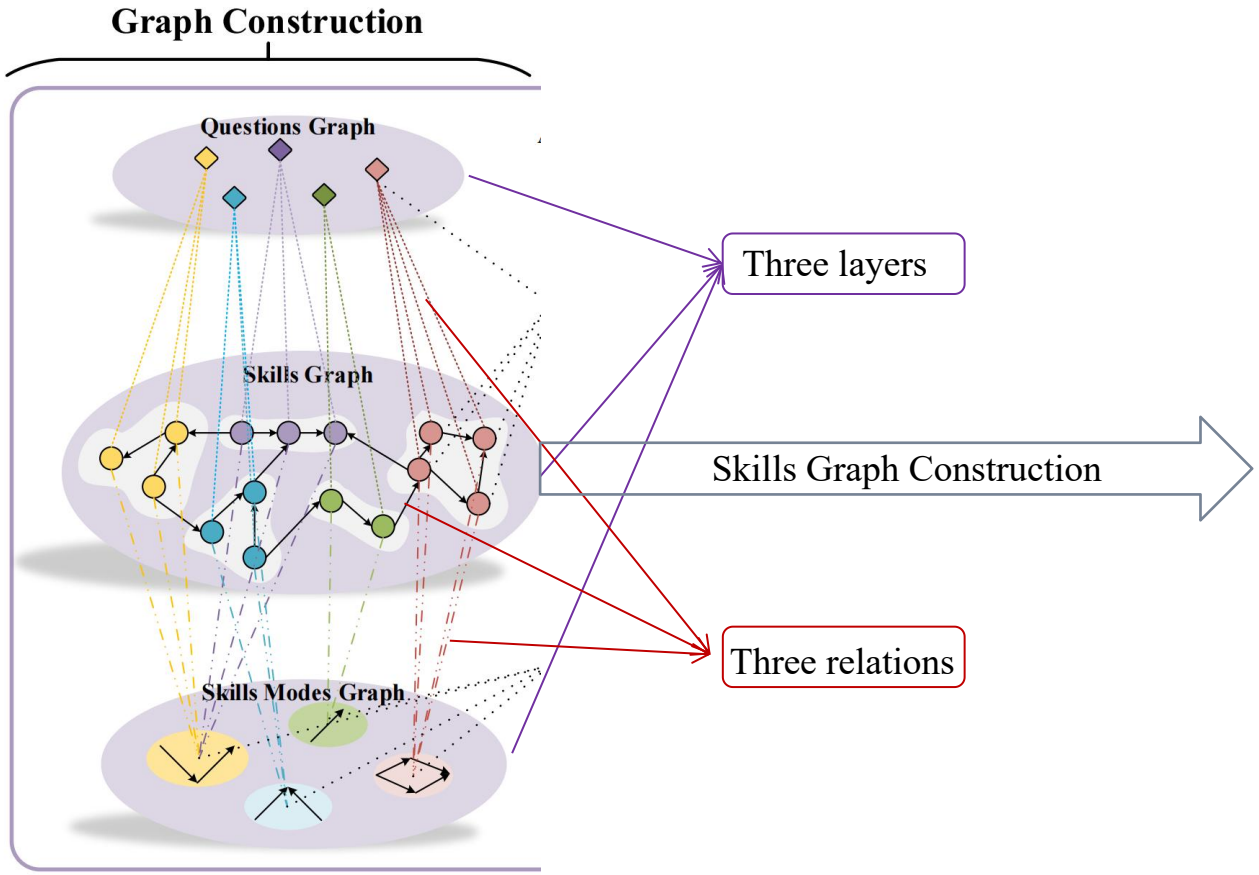


Fig. 3. Structure of the Graph.

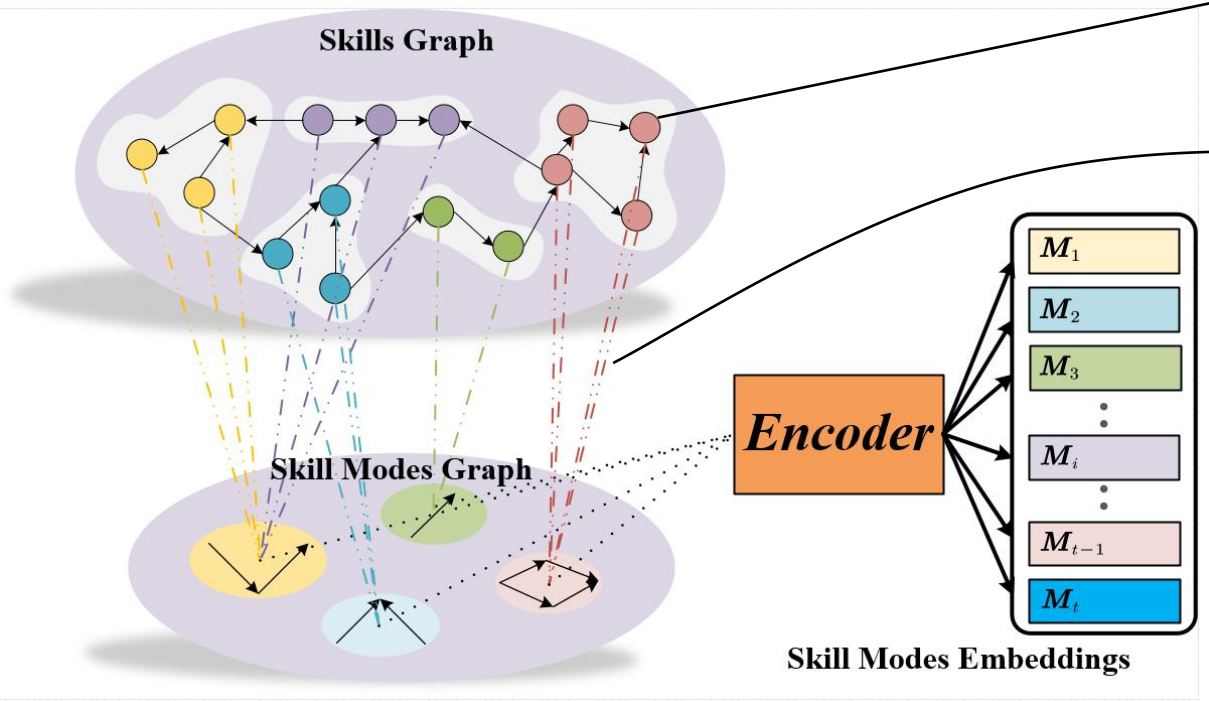
Frequency-based method

Frequency-based method generates a connected graph according to the number of times two skills appear together in the same question and the number of times two skills appear separately in different questions.

$$SS_{i,j} = \frac{n_{i,j}}{\sum_{k=1}^{n_s} n_{i,k}},$$

where $n_{i,j}$ represents the times two skills appear together in the same question.

Proposed Model



$$Diff_{s_i} = \frac{n^i}{N^i},$$

$$m_i = Flatten(\sum_{i' \in Idx_i} \sum_{j' \in Idx_i} SS_{i',j'}),$$

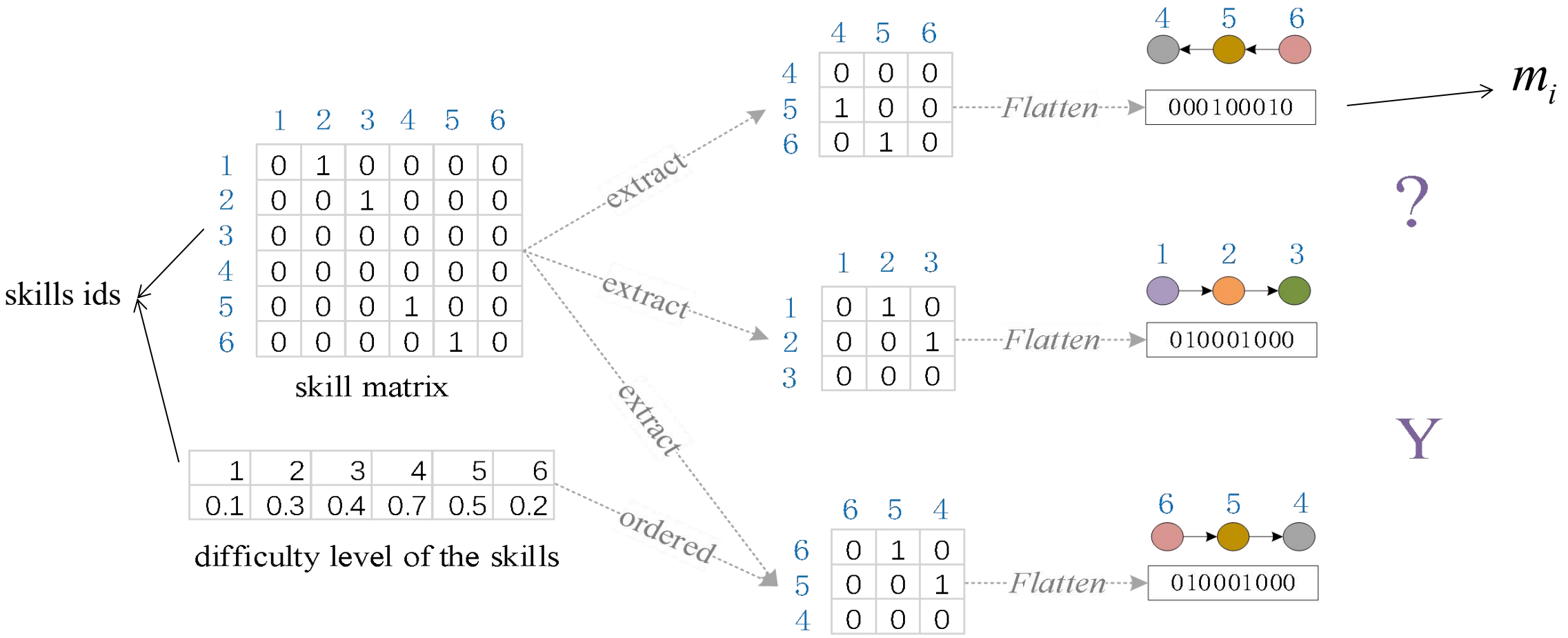
$$M_i = \sigma(W_M \times m_i + b_M)$$

$$Reloss = \frac{1}{n_q} \sum_{1}^{n_q} (M_i - m_i)^2$$

Fig. 3. Skill Modes Generation and Representation.

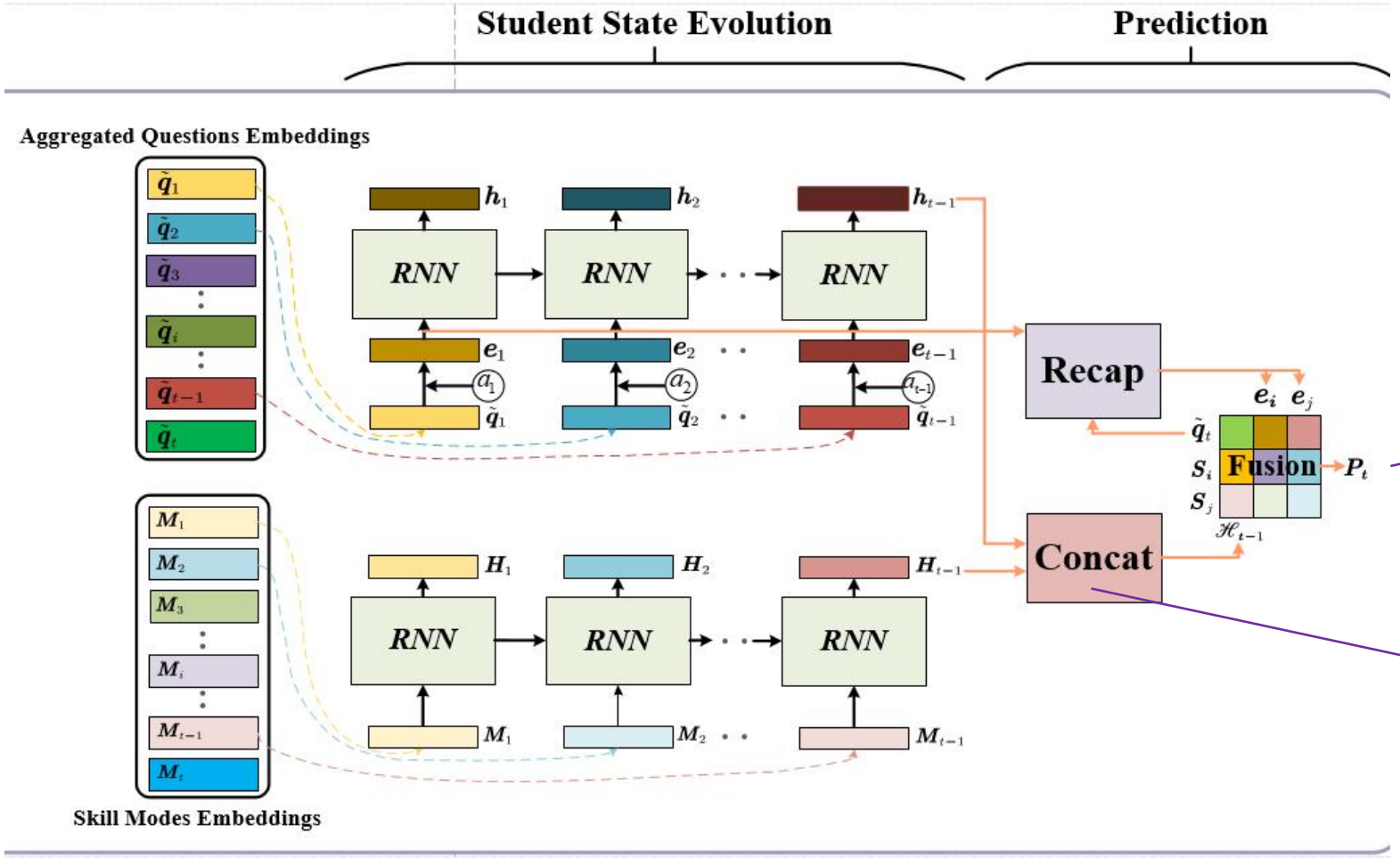
Graph Construction and Representation

Proposed Model



Graph Construction and Representation

Proposed Model



$$\alpha_{i,j} = Softmax_{i,j}(W^T[f_i, f_j] + b),$$

$$p_t = \sum_{f_i \in I_e \cup \{\mathcal{H}_t\}} \sum_{f_j \in \tilde{\mathcal{N}}_{q_t} \cup \{\tilde{q}_t\}} \alpha_{i,j} g(f_i, f_j),$$

$$\mathcal{H}_t = [h_t, H_t],$$

Student State Evolution and Prediction

Experiments

Experiments are conducted on five real-world datasets to demonstrate the effectiveness of the proposed model. The comparing results and Nemenyi tests are presented. Finally, the parameters in the model are analyzed.

Table 1. Dataset statistics

Datasets	assist09	assist09-muti	CSEDM	FrcSub	Math1	Math2
Number of students	3002	1793	343	536	4209	3911
Number of questions	17705	3014	236	20	15	16
Number of skills	123	54	18	8	11	16

Table 2. Comparison in terms of AUC

Dataset	DKT [8]	DKVMN [16]	GKT [10]	GIKT [11]	APGKT (Our model)
assist09	0.6995	0.7112	0.7230	0.7742	**0.7767**
assist09-muti	0.6961	0.7106	0.7320	0.7763	**0.7817**
CSEDM	0.7543	0.7626	0.7647	0.7836	**0.7902**
FrcSub	0.8891	0.8729	0.8748	0.8982	**0.9059**
Math1	0.8349	0.8403	0.8456	0.8892	**0.8922**
Math2	0.8084	0.8159	0.8181	0.8681	**0.8695**

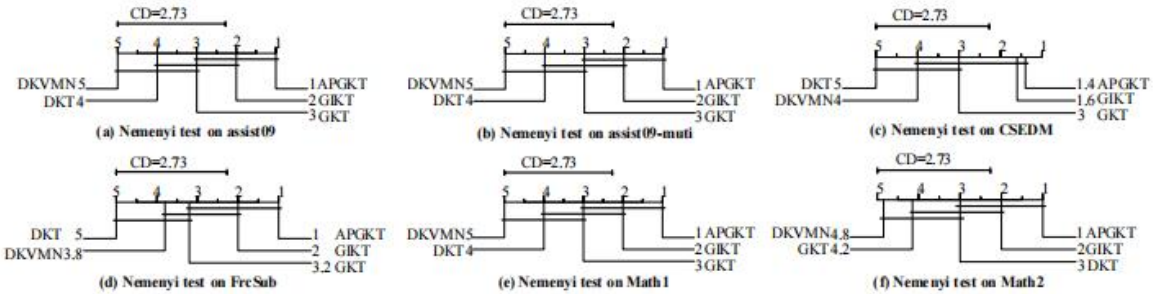


Fig. 4. Nemenyi test results of the proposed model and baselines. The results demonstrate the better performance of the proposed model.

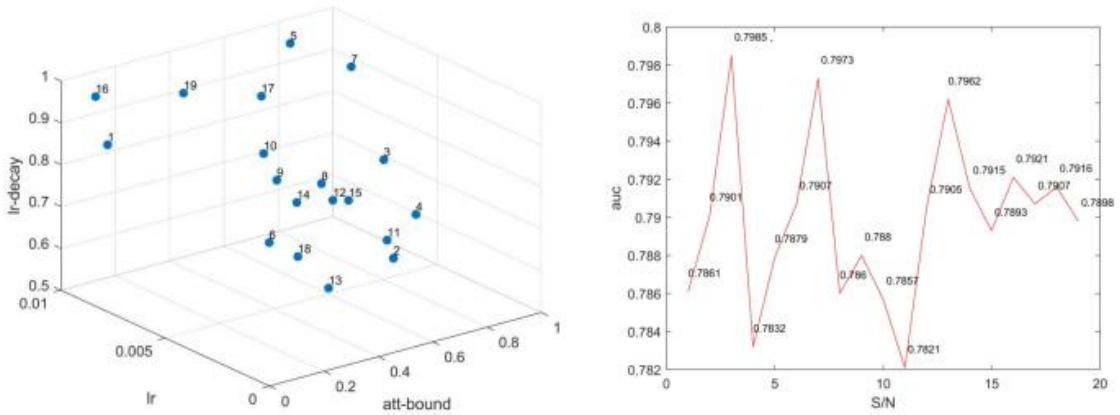


Fig. 5. Parameter analysis for APGKT. It is observed that our model outperforms the baselines although the parameters underwent constant changes.

Conclusion

合肥工業大學

Main Contributions

- **This study exploits the associative path on the skills graph for knowledge tracing (KT)**. The thinking process (i.e., obtaining the associative path) has been demonstrated to be indispensable for achieving a correct answer (detailed in Fig. 1). However, most of the existing KT models only consider whether the set of skills involved in the question have been mastered when predicting a student’ s future answering performance.
- **The proposed APGKT model includes the concept of skill modes and higher order cognitive states.** Considering the dynamic process of students thinking and answering questions, the skills associated with a specific problem are considered as a whole to consider the organizational association. We combine the cognitive state of the skills and the skill modes into a higher-order cognitive state to accurately represent the cognitive processes of students.
- **Extensive experiments on five public datasets proved that the prediction results of our model are better** than those of baseline models, owing to the consideration of the thinking process during KT.

Outlook

- Since the thinking process of students is actually a complex cognitive process, which is affected by many factors such as psychology, in the future, we will **further explore the representation and application of the thinking process** to improve the model.

PRICAI 2022

合肥工業大學

Thanks!

The 19th Pacific Rim International Conference
on Artificial Intelligence

November 11th, 2022

Haotian Zhang