# Research on High School Math Exercise Recommendation Based on Graph Neural Network

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# Outline

# Research Background
## Objectives

- Knowledge State Monitoring
- Learning Resource Recommendation
- High School Math (Chinese)

# Research Background

## Existing Problems

**Inappropriate Recommendation** Exercise recommendation is not based on knowledge mastery

**Disorganized exercise** Labelling knowledge for exercises lacking knowledge tags

**Knowledge evaluation** The difficulty for obtaining knowledge mastery proficiency of the student

**Exercise recommendation** How to recommend appropriate exercises according to their knowledge status

# Research Cores

## Exercise knowledge labeling

A multi-knowledge point labeling algorithm for high school mathematics exercises based on bidirectional LSTM (Bi-LSTM) [1] and graph convolutional neural network (GCN) [2].

## Knowledge tracing

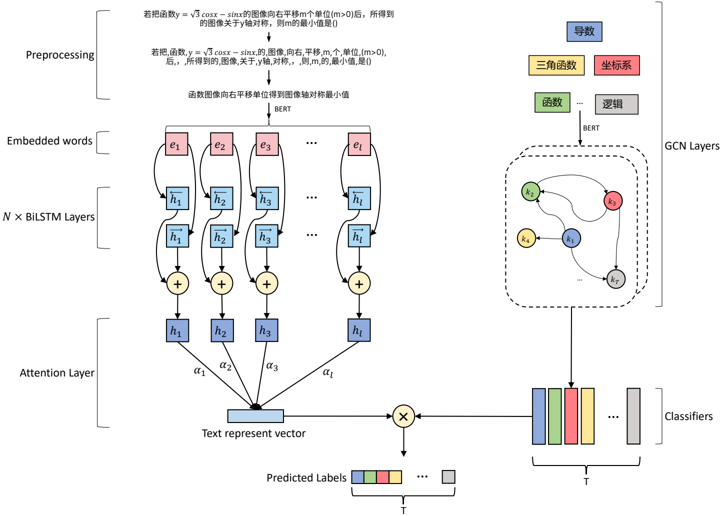
An improved graph-based DKVMN [7] knowledge tracing model to evaluate the knowledge proficiency of students.

## Exercise recommendation

A mathematical exercise recommendation model based on Matching-Ranking [5].

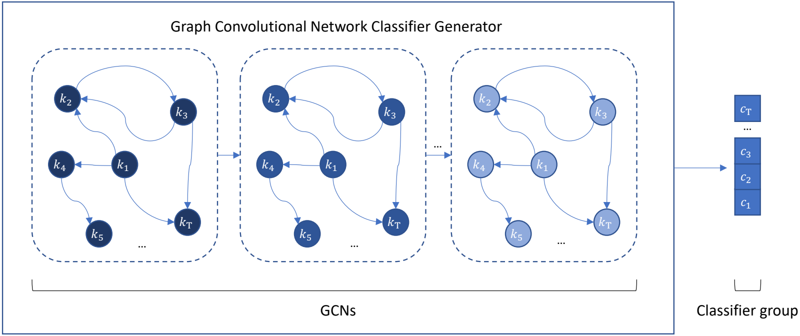
# Exercise Knowledge Labelling

## Architecture



# Exercise Knowledge Labelling

## GCN-based Classifier Generator



# Knowledge Tracing
## Problem Description

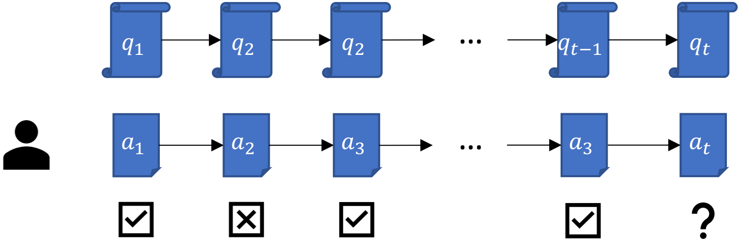
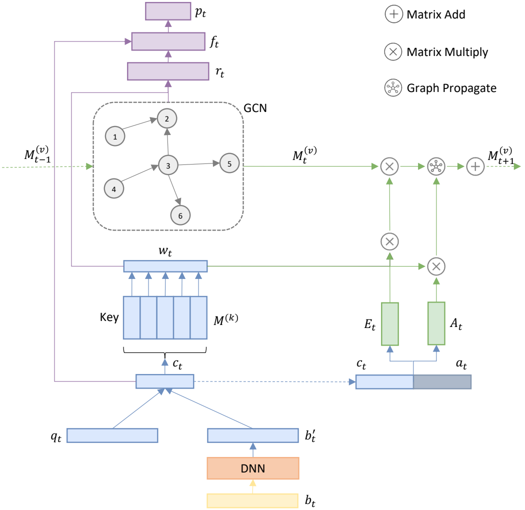



Figure: Knowledge tracing modeling

# Knowledge Tracing

## Architecture



# Knowledge Tracing

## Question-Knowledge Relation Modelling

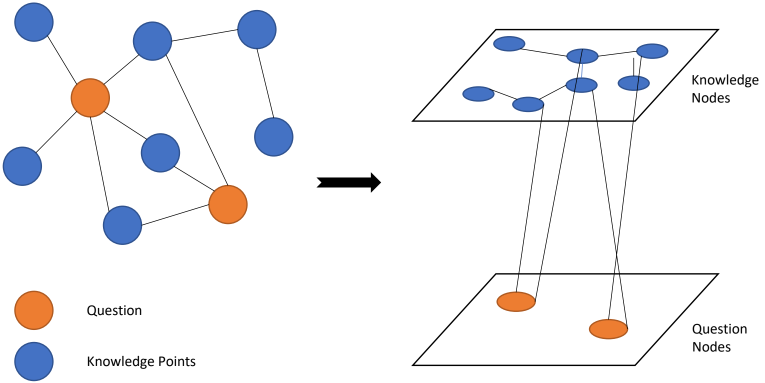



Figure: Relation modeling of exercise question and knowledge points

# Exercise Recommendation
## Architecture

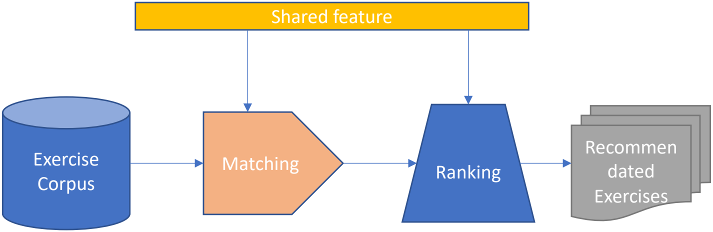
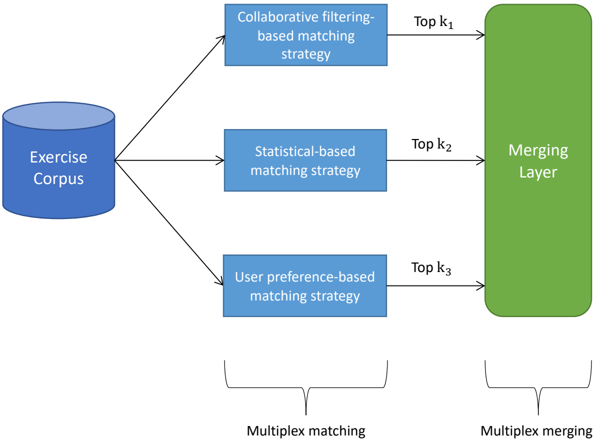


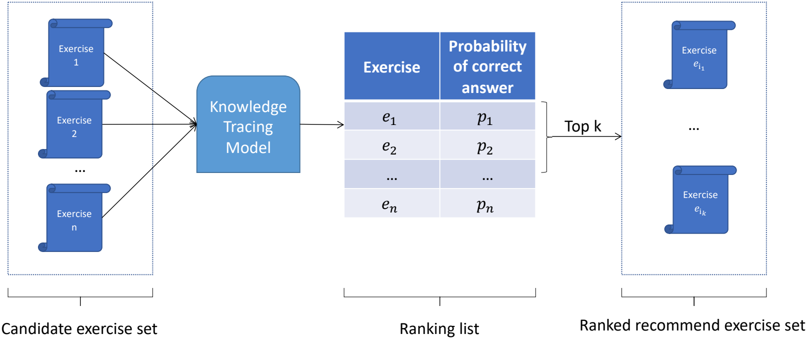

Figure: The architecture of recommendation model

# Exercise Recommendation
## Matching Phase



# Exercise Recommendation

## Ranking Phase



# Experiment Design

## Exercise Knowledge Labelling

- Compare with several baseline models
- Evaluate the multi-label classification performance

# Result Analysis

## Exercise Knowledge Labeling

Table: The performance comparison between baseline and proposed knowledge labelling models.

| Metrics | $\mathrm{F1}_{macro}$ | $\mathrm{F1}_{micro}$ | $\mathrm{Acc}_{ML}$ | $\mathrm{F1}_{ML}$ |
|---|---|---|---|---|
| BiLSTM+Attention | 0.824 | 0.924 | 0.874 | 0.926 |
| fastText | 0.846 | 0.922 | 0.854 | 0.916 |
| TextCNN | 0.761 | 0.923 | 0.857 | 0.917 |
| **Proposed** | **0.912** | **0.932** | **0.888** | **0.937** |

# Result Analysis

## Exercise Knowledge Labeling

Table: The multi-label classification performance of proposed model.

| Class | Precision | Recall | F1 Score | Support |
|---|---|---|---|---|
| 三角函数 | 0.957 | 0.710 | 0.815 | 31 |
| 函数奇偶性 | 0.946 | 0.930 | 0.938 | 187 |
| 导数 | 0.918 | 0.866 | 0.892 | 247 |
| 平面向量 | 0.942 | 0.961 | 0.951 | 204 |
| 数列 | 0.996 | 0.971 | 0.983 | 243 |
| 逻辑与命题关系 | 0.958 | 0.883 | 0.919 | 180 |
| 集合 | 0.907 | 0.867 | 0.886 | 45 |
| Micro avg | 0.951 | 0.915 | 0.932 | 1137 |
| Macro avg | 0.946 | 0.884 | 0.912 | 1137 |
| Weighted avg | 0.951 | 0.915 | 0.932 | 1137 |
| Samples avg | 0.951 | 0.935 | 0.937 | 1137 |

# Experiment Design

## Knowledge Tracing

### Basic Method

Compare with other KT baseline models BKT [6], DKT [4], DKVMN [1] and GKT [3]

Table: Dataset Statistics

| Dataset | #students | #exercises | #knowledge points | #interactions |
|---|---|---|---|---|
| ASSIST15 | 19,917 | 102,396 | 100 | 709K |
| ASSIST17 | 1,709 | 4,117 | 102 | 943K |
| STATICS11 | 333 | 1,223 | 156 | 189K |

# Result Analysis
## Knowledge Tracing

Table: The performance comparison between baseline and proposed knowledge tracing models.

| Model | ACC (%) | AUC (%) | Training time (sec) |
|---|---|---|---|
| DKT | $76.99 \pm 0.08$ | $81.79 \pm 0.09$ | $2,731$ |
| DKVMN | $75.63 \pm 0.19$ | $79.58 \pm 0.27$ | $3,378$ |
| NPA | $77.09 \pm 0.08$ | $81.81 \pm 0.13$ | $3,872$ |
| SAKT | $76.37 \pm 0.15$ | $80.77 \pm 0.09$ | $4,367$ |
| Proposed | $\mathbf{81.34} \pm \mathbf{0.25}$ | $\mathbf{83.20} \pm \mathbf{0.25}$ | $4,597$ |

# Experiment Design
## Exercise Recommendation

- Compared with conventional Collaborative Filtering and Random Recommendation
- Using adapted KT dataset for testing
- Check if the selected exercise is in the final recommendation list

# Result Analysis

## Exercise Recommendation

Table: The performance comparison between baseline and proposed recommendation models.

| Model | ACC | AUC |
|---|---|---|
| CF | 0.6329 | 0.6627 |
| DKT | 0.7741 | 0.7906 |
| Proposed | **0.7997** | **0.7923** |

# Conclusion

- The three modules of the proposed model satisfy the requirements of the design
- The proposed model achieves better performance compared with baseline models.

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