Liu JY, Wang F, Ma HP *et al*. A probabilistic framework for temporal cognitive diagnosis in online learning systems. JOURNAL OF COMPUTER SCIENCE AND TECHNOLOGY 38(6): 1203−1222 Nov. 2023. DOI: 10.1007/s11390-022-1332-5

A Probabilistic Framework for Temporal Cognitive Diagnosis in Online Learning Systems

Jia-Yu Liu(刘嘉聿), Fei Wang(汪飞), Hai-Ping Ma(马海平), Zhen-Ya Huang(黄振亚), Qi Liu(刘淇), En-Hong Chen(陈恩红), Yu Su(苏喻)

Research Objectives

- In intelligent education systems, cognitive diagnosis is used to analyze students' knowledge states, which is important to achieve personalized and intelligent education.
- Our research aims at establishing a cognitive diagnosis framework for online learning scenarios, which considers the temporality and randomness of students' proficiency evolving, and contains unified training and inferencing methods.
- The proposed method can better model the evolution of students' proficiency, and provide more accurate diagnosis results.

Research Method

- Inspired by the characteristics of proficiency evolution, the paper puts forward the assumption that students' proficiency varies as a Wiener process, modeling the temporality and randomness simultaneously.
- After that, based on the relationship between student states and exercising answers, the paper hypothesizes that the answering result at time k contributes most to inferring a student's proficiency at time k, which also reflects the temporality aspect, and enables us to get analytical M-step in the EM algorithm, further achieving the goal of unified training and inferencing processes.
- Finally, we demonstrate that the proposed UTIRT framework is general to cover traditional methods including IRT, MIRT, and TIRT.

Research Results

We conduct multiple experiments from 3 perspectives on 2 datasets.

- From the perspective of knowledge proficiency estimation, UTIRT improves ACC relative to 10 baselines by 0.8%—10.1%, while improving AUC by 0.3%—11.4% and decreasing RMSE by 0.2%—5.2% on ASSIST and Junyi. The improvement is more obvious on data with stronger temporality. Relationships between knowledge concepts, suitable hyper-parameter are also beneficial to cognitive diagnosis.
- From the perspective of next score prediction, UTIRT obtains the best ACC (improves 0.5%—9.9%) and AUC (improves 0.1%—12.2%).
- In temporality utilization analysis, that inconsistent training and inference methods will lead to contradiction is verified through hypothesis testing (p-values on ASSIST and Junyi are 4.61×10^{-6} and 6.08×10^{-3} respectively). Besides, UTIRT's prediction accuracy is always better than TIRT with different “keep length", which further demonstrates the importance of unified training and inferencing processes.

Research Conclusions

- This paper proposes a UTIRT framework for online learning scenarios that models the temporality and randomness of students' proficiency evolving. Experimental results show that both temporality and randomness are important and have significant influence on cognitive diagnosis results.
- Moreover, unified training and inferencing methods, the relationships between knowledge concepts and suitable hyper-parameter also improve diagnosis effects.
- For future research, some possible factors, such as multiple attempts, hints and clock time could be potentially helpful for cognitive diagnosis. How to incorporate them into students' proficiency evolving is the next research direction.