Developing a Mastery Learning Service for ASSISTments

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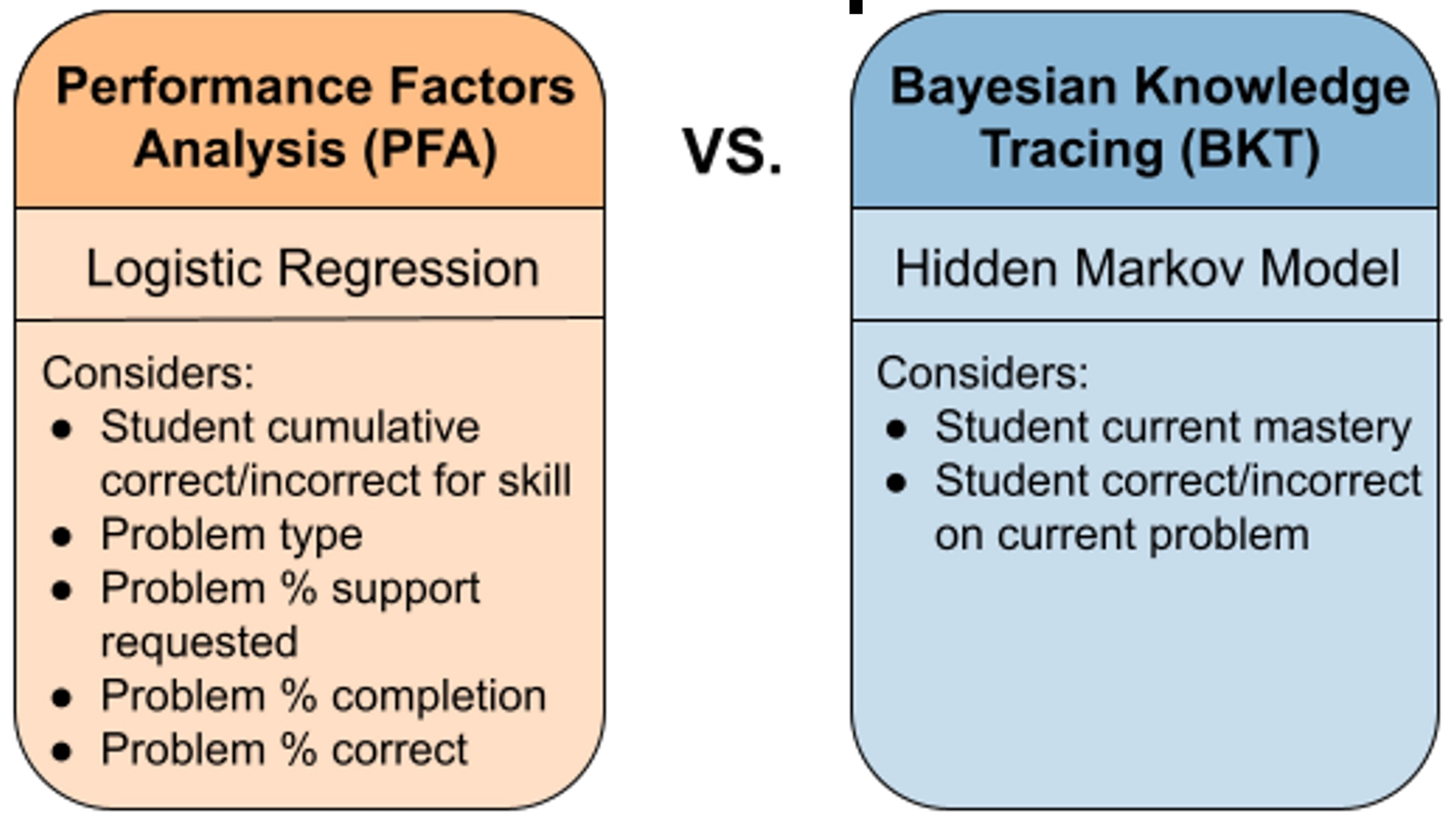
Background

Knowledge tracing, the practice of modeling and predicting student knowledge over time, has many applications for intelligent tutoring systems like ASSISTments. Our goal is to enable customized learning for students and provide data-driven insights for teachers, schools, and researchers by implementing a mastery learning service that **tracks and predicts student knowledge in real time**.

Data Gathering

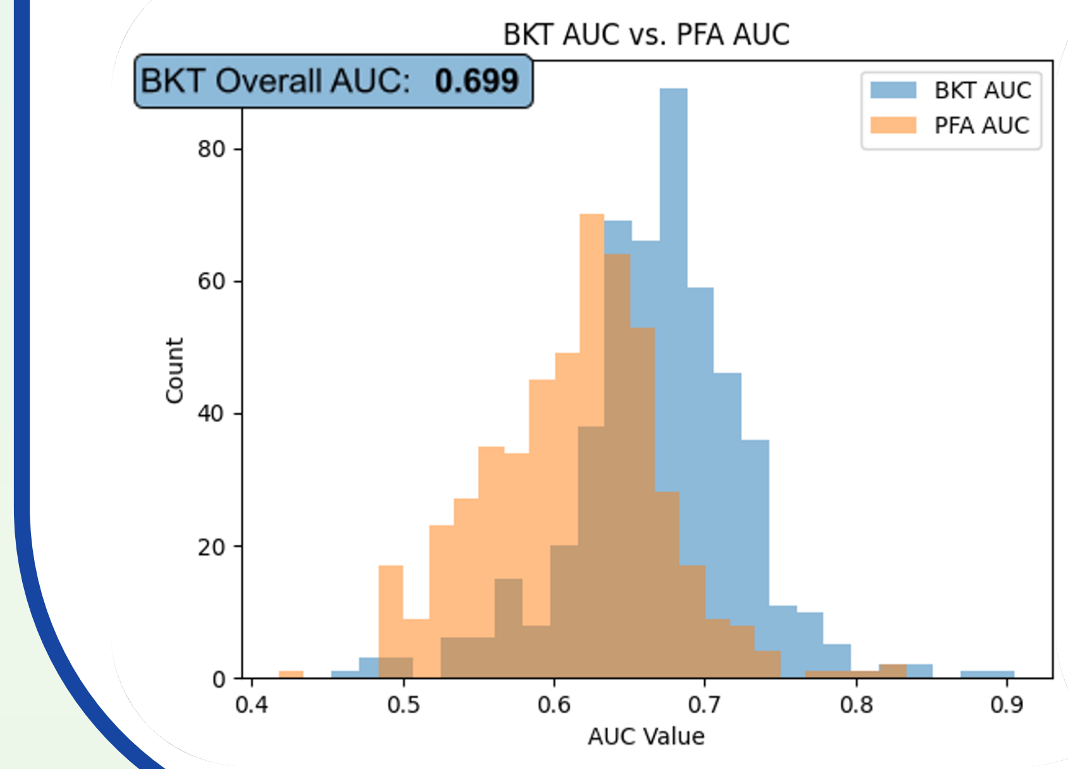
- ASSISTments problem logs since June 2022 (~14m rows)
- Maximum first 100 logs for each student on a single skill
- Discard students w/ only one log on a skill from train set [2]
- 70/30 train/test split such that no students are in both sets

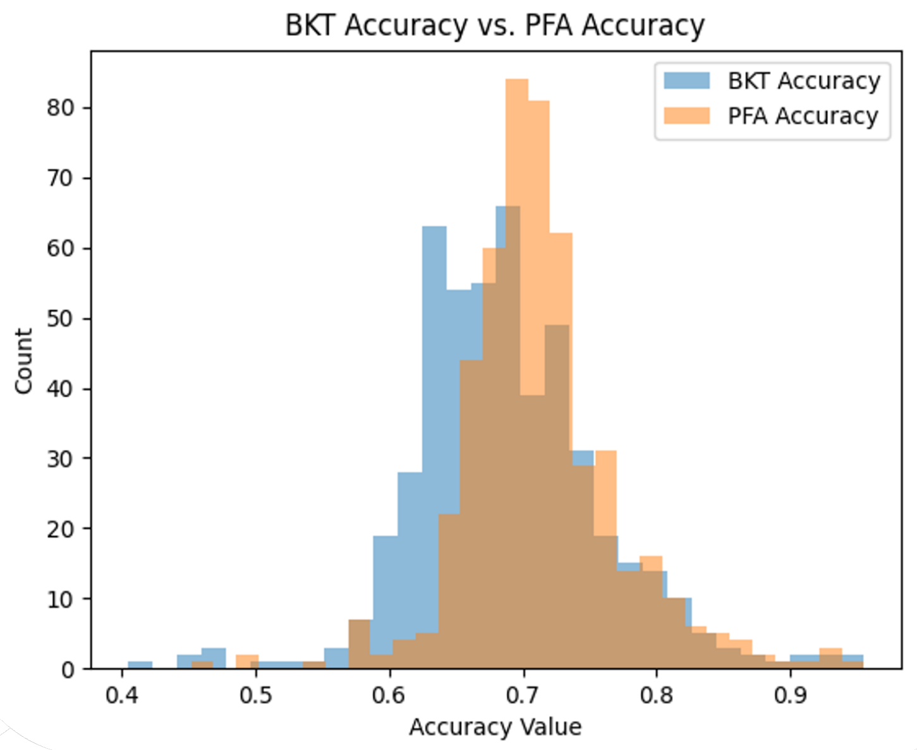
Model Comparison


Performance Factors Analysis (PFA)
vs.
Bayesian Knowledge Tracing (BKT)
Logistic Regression
Hidden Markov Model

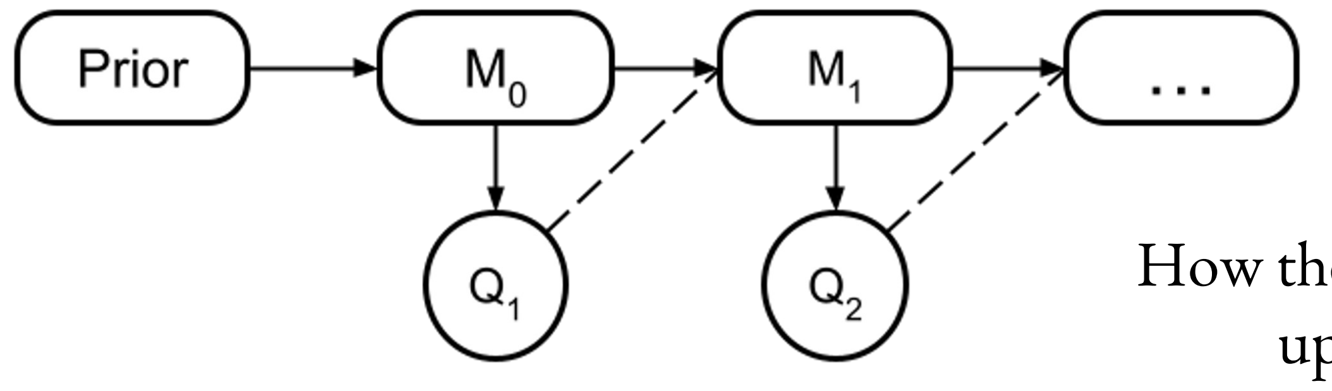
Considers:
- Student cumulative correct/incorrect for skill
- Problem type
- Problem % support requested
- Problem % completion
- Problem % correct

Considers:
- Student current mastery
- Student correct/incorrect on current problem





BKT Architecture



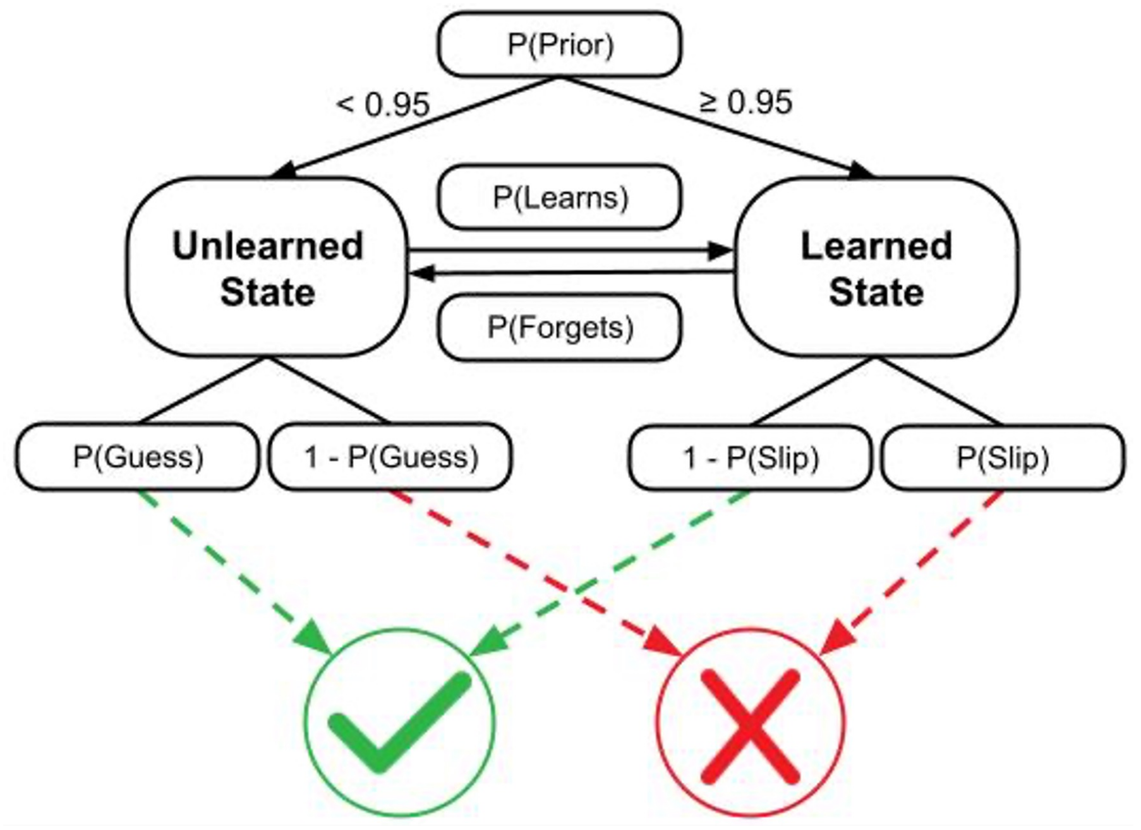
Prior = M_0	Default mastery prediction for skill
M_n	Mastery prediction after n questions
Q_n	n^{th} question

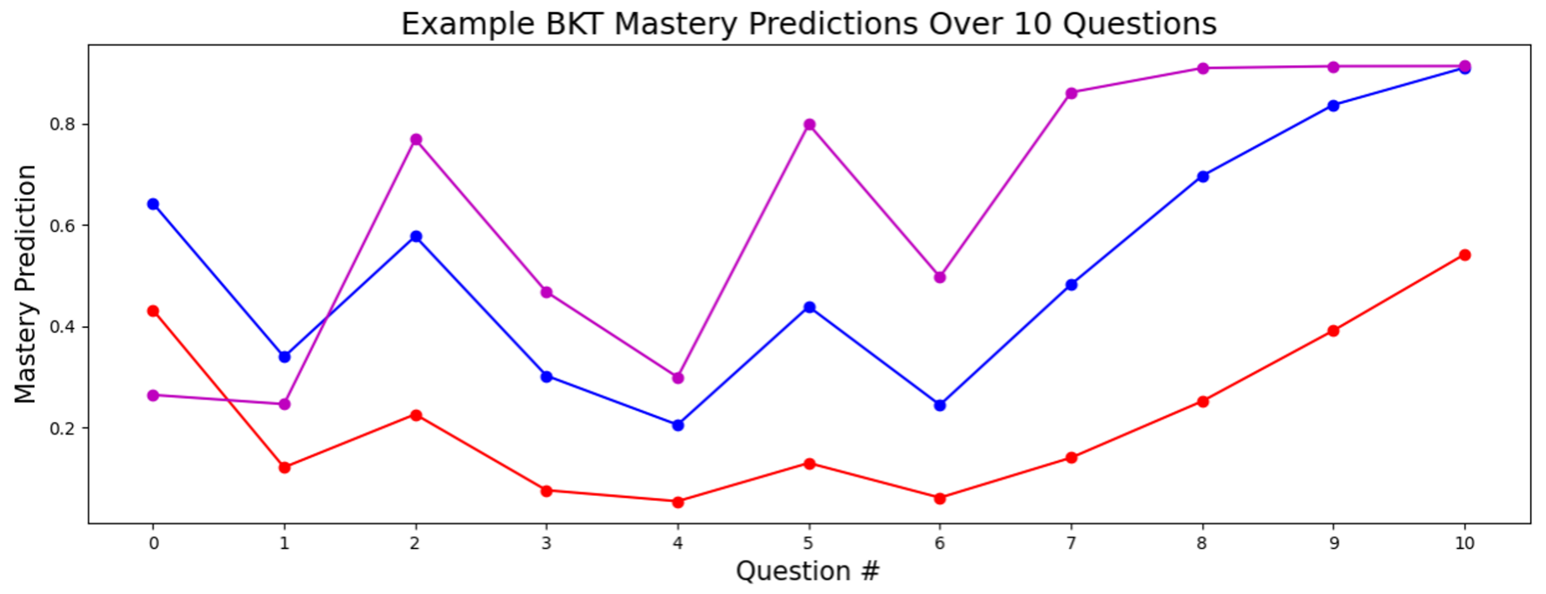
How the BKT mastery prediction is updated after a question

Model Params:

P(Prior)	Student knows the skill
P(Learns)	Student acquires the skill
P(Forgets)	Student forgets known skill
P(Guess)	Correct on an unknown skill
P(Slip)	Incorrect on a known skill

How BKT models a student applying their knowledge on a single question



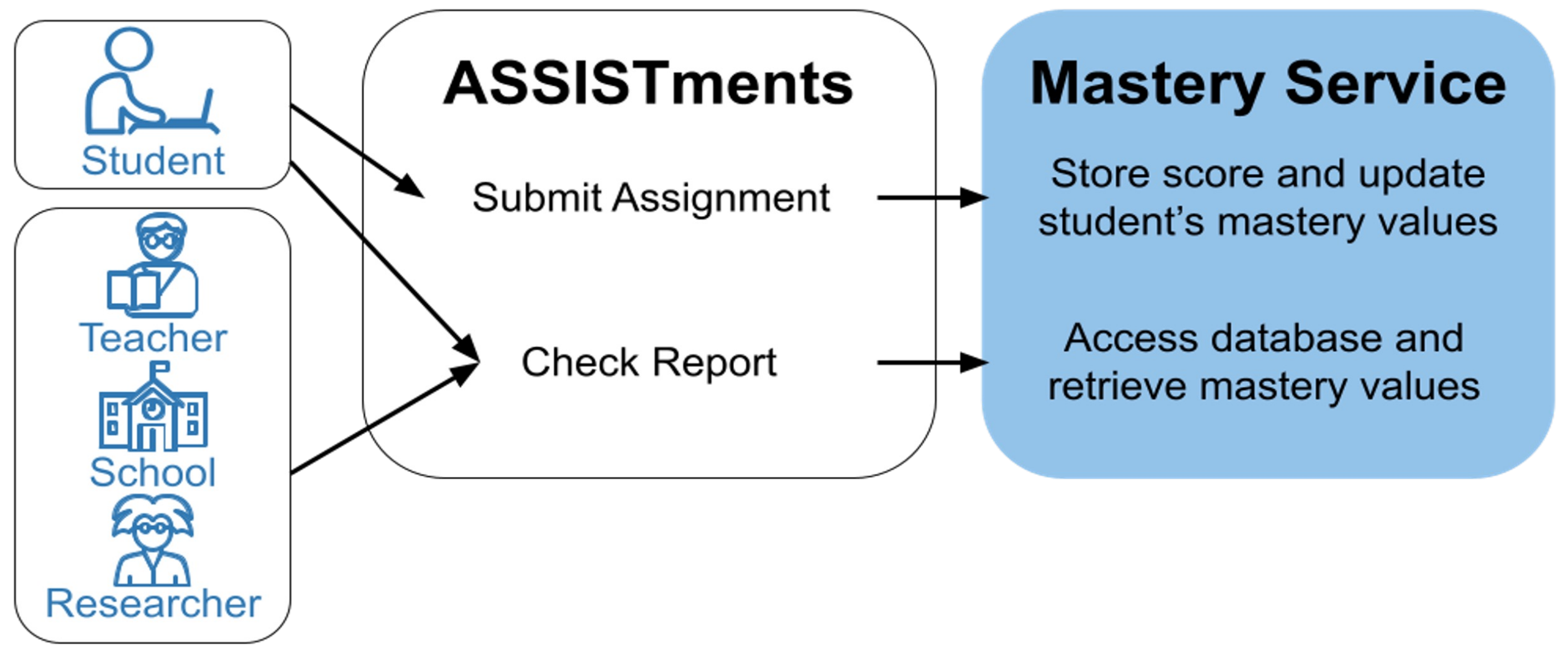


Skill	Prior	Guess	Slip	Learn	Forget
● Compare 2-digit numbers	0.432	0.556	0.051	0.452	0.006
● Adding whole numbers	0.642	0.442	0.091	0.150	0.018
● Add 3 whole numbers within 20 in context	0.264	0.072	0.163	0.203	0.081

How BKT mastery predictions change over 10 questions for three skills

Try a BKT simulation!

Use Case Flow


Student
Teacher
School
Researcher
ASSISTments
Submit Assignment
Check Report
Mastery Service
Store score and update student's mastery values
Access database and retrieve mastery values

Discussion

- BKT model outperforms PFA model
- Other BKT studies have better-performing models [1, 2]
- Exclusion of some skills with inaccurate models
- BKT model improves as student does more problems
- Development of API vs. how the API is used

Next Steps

- Integrate mastery service into the ASSISTments platform
- Fix some issues with pyBKT Python library [1]
- Develop an error metric for reliability of BKT
- Compare to other knowledge tracing models including Factorization Machines and Deep Neural Networks

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References: [1] Badrinath, A., Wang, F., Pardos, Z.A. (2021) pyBKT: An Accessible Python Library of Bayesian Knowledge Tracing Models. In S. Hsiao, & S. Sahebi (Eds.) *Proceedings of the 14th International Conference on Educational Data Mining* (EDM). Pages 468-474.

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