A Bandits Approach to Intelligent Tutoring Systems using Concept Evolution Estimation

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Introduction

Conventional teaching methods take a one-size-fits-all approach – same course contents, evaluation methods, resources, etc.

Each learner is different, has different abilities and requirements. An Intelligent Tutoring System (ITS) tailors the course contents to each student.

Important Modules include User Interface, Domain Model, Student Model and the Instruction Model.

- Domain Model deals with what is being taught
- Student Model deals with who is being taught
- Instruction Model deals with how to teach

Related Work

There are many works in the field of ITS. We have listed below a few important works and the approach they take.

- [1] Lan, Biraniuk propose two UCB based algorithm CLUB & A-CLUB which fix the sequence of assessments & insert a learning action in between the assessments. Their aim here to maximize the learner’s score in the immediate next assessment.
- [2] Manickam et al. work with the same setting as above. The propose an algorithm based on Thompson Sampling & Knowledge Gradients.
- [3] Wang et al. take a POMDP approach to ITS where they use the questions asked by learners as observations & the answers the ITS provides as actions. However, they only allow (0,1) states concept values.

Most of the work mentioned above take a divided approach to it. Our aim to take a holistic approach to ITS.

Problem Setting & Assumptions

There are N learners & K concepts.

- Concept Vectors is in C_j ∈ [0,1]^K where C_j ⊂ [0,1] for j = 1,2,…N
- Learning Action could be anything such as Video lecture, book chapters, experiments. Assumed to give Beta Distributed learning push.
- Markovian Evolution: The learning level of a learner depends on his/her current knowledge level & the Learning Action chosen at current step.
- Noisy Feedback: We assume that we have at our disposal a noisy version of the learner’s concept vectors.

Method Proposed – Independent Concepts

We study two cases of the problem: Independent Concepts and the Dependent Concepts

In the independent case, there are no dependencies among the concepts. i.e., each concept could be taught irrespective of the learner’s knowledge about other concepts.

Update Equation

\[ c_i^{t+1} = c_i^t + \beta(\alpha_i, \beta_i, c_i) \cdot (1 - c_i^t) \] (1)

Parameters to Estimate here are the Beta Distribution parameters \( \alpha_i, \beta_i \) associated with each action. And there are 2K such parameters for each Action.

Method Proposed - Dependent Concepts

In the dependent concepts case, we assume a pre-requisite relationship among the concepts. Hence, before teaching a concept, its prerequisite concepts need to be taught.

Update Equation

\[ c_i^{t+1} = c_i^t + \sum_{j=1}^{D} \beta(c_j, c_i) \cdot (1 - c_i^t) \] (2)

where \( D \) is the number of prerequisite concepts to \( c_i \), and

\[ \sum_{j=1}^{D} \beta(c_j, c_i) = 1 \] (3)

Because of the update equation, our objective function becomes:

\[ f(\alpha_i, \beta_i) = \left( \frac{1}{1 + e^{-\alpha_i - \beta_i}} \right) - \beta(\alpha_i, \beta_i, c_i) \] (4)

Parameters to Estimate here are not just the Action Beta parameters, but also the lambda parameters involved.

We propose the Bandits based Parameter Estimation for Concept Evolution (BPECE) algorithm as shown in Algorithm 1.

Results

![Graphs showing results of the experiments]

References