IMPLEMENTATION OF AN ADAPTIVE LEARNING SYSTEM USING A BAYESIAN NETWORK

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ABSTRACT

An adaptive learning system is proposed that incorporates a Bayesian network to efficiently gauge learners' understanding at the course-unit level. Also, learners receive content that is adapted to their measured level of understanding. The system works on an iPad via the Edmodo platform. A field experiment using the system in an elementary school begins in September, 2014. In addition to the contents of this paper, reports on the field experiments and a demonstration will be given at the conference poster presentation.

KEYWORDS

Adaptive testing, Adaptive learning, Bayesian net, Edmodo

1. INTRODUCTION

Smart phones and tablet devices are now widely used. According to Cabinet Office research in 2013, the family unit penetration rate in Japan reached 54.7% for smartphones and 20.9% for tablet devices. Looking at the educational situation in Japan, the Ministry of Education, Culture, Sports, Science and Technology (MEXST) has set a goal of reaching a 100% penetration rate among students in elementary, junior high and high schools by 2020.

In this situation, the first task is to digitize the learning material. After simple digitization, we should address the challenge to use learners' learning logs to create tailor-made learning material that promotes efficient and motivated learning. In this paper, we propose an adaptive learning system that constructively uses learners' logs as part of its implementation scheme. Section 2 explains the basic theory and implemented system. Section 3 deals with the ongoing field experiments. Section 4 concludes the paper.

2. NETWORK-BASED ADAPTIVE TESTING

The system has 2 modes: testing mode and learning mode. The testing mode gauges learners' understanding in each course unit using the Expected Value of Network Information (EVINI)-based adaptive testing scheme (Ueno *et al*., 1994). EVINI was inspired by the Expected Value of Sample Information (EVSI) (Raiffa 1961) concept from decision theory. In the proposed system, the learning mode assigns each learner drills on course units that the learner is not good at. Compared to the adaptive test using conventional item response theory (Birndaum 1968), this network-based adaptive testing method enables more detailed modeling of the relationship of the course units. The Bayesian net framework (Pearl 1989) is used to calculate EVINI. The details are explained in 2.2.

2.1 System Configuration

Figure 1 shows the configuration of the proposed system. The WEB application server runs HTML5-based drill contents for both modes. In the testing mode, the system automatically sets testing units for each learner. The unit selection is based on EVINI, which is computed using the learner's previous answers. To calculate

EVINI, a Bayesian net server infers the probability that the learner has understood each of the not-yet-set units, by examining the accuracy of previous answers. Details of EVINI are explained in 2.2. The database server stores learners' logs, which contain each learner's drill answers.

Table 1. Schedule of the field experiments

Phase type	Period
Data collection phase	September, 2014 to October, 2014
Adaptive learning phase	October, 2014 to February 2015
System Evaluation phase	March, 2015

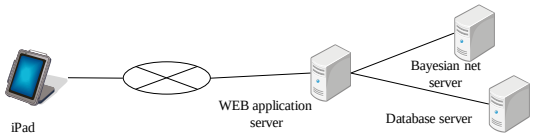

Figure 1. System configuration

2.2 Basic Theory

A Bayesian network framework is used to build an inference model of learners' understanding. The model structure and conditional probability table (CPT) are trained on preliminarily collected learners' logs. Each node of the Bayesian network relates to a course unit of content, and each node has 2 values, "understanding" and "not understanding," denoted by "1" and "0". In the testing mode, at the conclusion of questioning for each unit, the system uses the Bayesian network to infer the probability that the learner understands the units that they have not yet worked through. We denote the set of the units as "***N***". Using the conditional probability given by the inference, the system selects the most informative units ($\hat{j}$) calculated by Eq. 1 as the next testing units.

$$\hat{j} = \arg\max_{j \in N} EVINI_j \qquad (1)$$

$EVINI_j$ is given by the following formula.

$$EVINI_j == \sum_{x_j=0,1} P(x_j) \sum_{X_l \in X_L} P(X_l \mid x_j) \log P(X_l \mid x_j) - \sum_{X_l \in X_L} P(X_l) \log P(X_l)$$

Where X_l is a pattern vector (understanding pattern) in a set of nodes that consists of the *j*-th node and its child and parent nodes. Thus, $P(X_l)$ is a joint probability. X_L is the set of pattern vectors for the *j*-th node and its child and parent nodes.

The testing mode continues until forward testing is no longer expected to provide a preselected level of network information gain, i.e., the maximum value of $EVINI_j$ in Eq.1 becomes smaller than a threshold.

3. ONGOING FIELD EXPERIMENTS

We started field experiments with the system in a real-world classroom in September, 2014. The goal of the field experiments is to evaluate the proposed system, which uses learners' logs to guide adaptive learning.

The participants are 89 students in the 5th grade. The course material covers 4th to 6th grade math drills consisting of 43 course units. The implemented system works on an iPad via the Edmodo platform (https://www.edmodo.com/) .

Table 1 shows the schedule of the field experiments at a public elementary school in Japan. We collect students' logs in the data collection phase. Using the data, the Bayesian network structure and CPT are trained. The adaptive learning phase is the central focus of the actual field experiments, using the system explained in Section 2. We plan to evaluate the system in terms of learning outcomes and usability with an achievement test and questionnaire.

4. CONCLUSIONS

In this paper, we explained the implementation of a Bayesian network based adaptive learning system. The system will provide a way to use the learners' logs to facilitate efficient learning.

We also provided information on ongoing field experiments with the system at an elementary school in Japan. We plan to evaluate the system from the viewpoint of learning effectiveness and usability in the near future.

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