So, H. J. et al. (Eds.) (2020). Proceedings of the 28th International Conference on Computers in Education.
Asia-Pacific Society for Computers in Education

Predicting Stag and Hare Hunting Behaviors Using Hidden Markov Model

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Abstract: In this paper, we used Hidden Markov Model (HMM) to describe the gaming behaviors of students and whether they will exhibit "stag" or "hare" hunting behavior in a mobile game for mathematics learning. We found that there is a 99% probability that the students will stay either as stag or hare hunters. Our results also suggest that they would choose arithmetic problems involving addition. These game behaviors are not beneficial to learning because they are only exhibiting mathematical skills they already know. The results of the study show that stag and hare hunters have unique traits that separate the one from the other.

Keywords: collaborative learning, game behavior, mathematics, mobile learning, mobile games

1. Introduction

A collaborative learning environment posits that students learn while they are in a social group (Gillies, 2016). As social learners, students may display varying degrees of participation (Bringula et al., 2018). Stag and hare hunting behaviors are the tendency of a leaner to contribute to the scores of the group by choosing either a high-risk mode but with higher points or a low-risk mode but with lesser points (Bringula & Rodrigo, 2019). This game behavior is relatively unknown in the field of a collaborative mobile learning environment. In this study, we attempted to describe the game behaviors of the students and predict whether students will exhibit the stag and hunting behaviors. The output of the study will serve as a basis in the development of adapted mobile-based learning for mathematics.

2. Method

This study used the dataset collected by Bringula and Rodrigo (2019). The dataset is composed of interaction log files that were generated through the use of a mobile collaborative game named *Ibigkas!Math*. It is a mobile-based learning application for grades 1 to 6 students. It is a collaborative game that covers arithmetic problems (addition, subtraction, multiplication, and division of whole numbers and fractions). The students utilized the mobile game for 15 minutes in an experiment conducted during their class session. The application generates arithmetic problems and it displays in one of the team members' mobile devices. The player has to read aloud the arithmetic problems. The answers are presented in multiple-choice. The correct answer will appear in one of the team members' devices. The complete description of this game is discussed extensively in Bringula and Rodrigo (2019).

The dataset contains 4,628 solved problems. The log files have six features, such as difficulty level, type of problem solved, speed, time spent, and the number of correct attempts. The difficulty level and type of problem solved are game modes. In the difficulty level, students may choose a very easy (ve), easy (ea), medium (md), hard (ha), or very hard (vh) game setting. The type of problem solved is the type of arithmetic problems (i.e., addition (add), subtraction (sub), multiplication (mul), division (div)) that the student attempted to solve. Students were informed that prizes would be awarded to three groups of students with the highest game scores. Twenty-five boys and 12 girls with an average of 11 years old participated in the study. They had varying degrees of mathematics abilities – eight were low-performing, 13 were average-performing, and 16 were high-performing.

Speed is a game setting that determines the pace of the game. Students may choose a very slow (2 points), slow (5 points), medium (10 points), fast (15 points), or very fast (20 points) mode. Students were informed that there were no deductions of points for wrong answers but on the time limit. Students that chose the first-three settings were labeled as hare hunters; otherwise, they were labeled as stag hunters. We used the hidden Markov model (HMM) to predict whether students would exhibit a stag or hunting behavior given the sequence of difficulty level and type of problem solved. These variables were used because we found in our separate study that these were the significant variables of a decision tree model that could classify stag and hare hunter behaviors (Bringula & Rodrigo, 2020). There are 20 possible game settings (or states) (5 difficulty problems times 4 types of problem) that a participant may choose from. Furthermore, there are 400 possible transitional states (20 states multiplied by 20 states). Initial probabilities for the HMM were determined based on the log files. HMM using the Viterbi algorithm was implemented in Jupyter Notebook. Ten random samples with ten random observations were fed into the HMM model to determine the possible game behavior of the students. The number of random observations is based on the average number of questions a student can solve per game session. On average, one student solved nine questions per game session.

3. Results and Discussion

We found that there is a very high probability (99%) that the students will stay at their current game behavior (Figure 1). The result suggests that the students will persistently choose a game mode based on the speed setting. This means that they will choose a game setting that they are comfortable with and are less likely to explore new game speed settings. This game behavior may not be beneficial to mathematics learning since students are only exhibiting the skills that they already know.

The graph in Figure 1 also shows that they choose only 10 states out of the 20 possible states. These states are easy and addition (eaadd), easy and multiplication (eamul), easy and division (eadiv), very easy and subtraction (vesub), very easy and addition (veadd), very hard and addition (vhadd), medium and addition (mdadd), medium and multiplication (mdmul), medium and subtraction (mdsub), and hard and addition (haadd). It is worth noting that they are more likely to choose problems involving addition. These game behaviors can be attributed to the fact that the goal of the students is to achieve high scores. It can be also observed from the figure that the distribution probabilities in hare hunters are scattered among the 10 states. The finding implies that hare hunters are solving diverse problems than stag hunters.

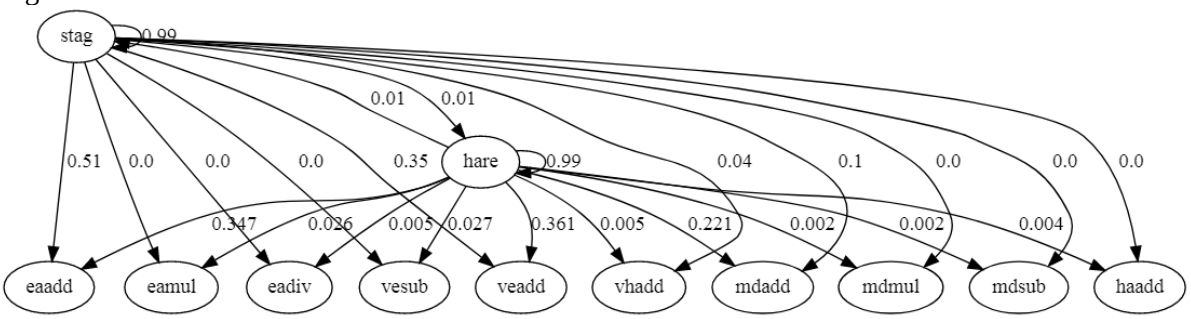

Figure 1. A hidden Markov model for relating the game mode settings to the game behavior (stag and hare)

Table 1 shows the three possible cases the students may exhibit during game sessions. The other seven possible cases have the same output as the first observation. It indicates that students are more inclined to be hare hunters – a "slowly but surely" game behavior. The results shown in Table 1 further confirm that hare hunters solve a variety of problems. The hare hunters will attempt all arithmetic problems with varying levels of difficulties.

Meanwhile, a stag hunter tends to solve very hard addition problems. Perhaps, they believe that they will gain more points by solving more difficult problems. Consistent with the definition of stag behavior, the students who chose to set the game mode in a faster setting are risk-takers. A faster game setting may incur higher points but the game imposes higher time deductions for every wrong answer. The HMM model can also predict that students may also shift from being a stag to a hare hunter (and vice versa). As previously shown, the shift in game behavior is very minimal. Nonetheless, it provides an opportunity for learners to explore more game settings.

Table 1. Predicted Game Behaviors Given the Game Settings

N	Observation1	Behavior	n	Observation2	Behavior	N	Observation3	Behavior
1	haadd	hare	1	vhadd	stag	1	vhadd	Stag
2	mdmul	hare	2	vhadd	stag	2	vhadd	Stag
3	mdsub	hare	3	vhadd	stag	3	vhadd	Stag
4	mdadd	hare	4	vhadd	stag	4	veadd	Stag
5	vesub	hare	5	vhadd	stag	5	vhadd	Stag
6	eadiv	hare	6	vhadd	stag	6	eadiv	Hare
7	vesub	hare	7	vhadd	stag	7	eamul	Hare
8	eamul	hare	8	vhadd	stag	8	mdadd	Hare
9	vesub	hare	9	vhadd	stag	9	veadd	hare
10	veadd	hare	10	vhadd	stag	10	vesub	hare

4. Conclusions and Future Work

This study aims to describe the game behavior of students who utilized a mobile game learning application in mathematics and predict whether they will exhibit a stag or a hare hunter game behavior. It is found that there is a very high probability that students will stay at the game settings they choose until the end of the game. Students that display a hare hunting behavior solve a variety of problems in an easy and slow pace manner. This is different from the students who are stag hunters. Stag hunters are risk-takers – solving more difficult problems also with a faster game setting. Thus, we found evidence that stag and hare hunters of a mobile game learning application have unique traits that separate the one from the other.

The results of this study will be implemented in the development of an adaptive version of *Ibigkas! Math*. The adaptive version will be then tested to determine the changes in the gaming behaviors of the students. Its influence on students' mathematics learning will also be investigated.

Acknowledgements

The researchers are indebted to Dr. Nieva Discipulo, Ellen Tabayan, UE Elementary and Senior High School Laboratory School staff, my research assistants, and to all participants of the study. This paper is funded by Engineering Research and Development for Technology.

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