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Rough set and machine learning approach for identifying flow experience in e-learning

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Abstract. Flow experience as a psychological theory has been implemented in various fields, especially in games and marketing. Flow is an optimal condition that someone feels immersed, focused and enjoy an activity. Based on this theory the psychological experience is represented as anxiety, boredom, and flow. Considering the psychological conditions in learning activities can improve the performance of students. Thus, involving the flow experience in learning process particularly in e-learning environment becomes very interesting and challenging. This challenge is how to identify the student flow experience during interaction students with the e-learning. In the previous study, flow was measured by conducting a series of questionnaires after a learning process. This is very inefficient, especially if applied in an adaptive e-learning. Additionally, this measurement is often unnatural, since it cannot capture the students learning behavior. Therefore, this study presented flow experience identification when students interact with e-learning using rough set and machine learning approach. Rough set is an efficient tool to solve the uncertainty, imprecision, and vagueness. While, the fuzzy rule and decision tree, as part of machine learning methods were implemented as a comparation. The identification was done using learning behavior parameters included duration of access, frequency of access, assessment score, and duration time to complete the assessment. As the results, the rough set can identify the flow experience with accuracy level is 92.92%. On the other hand, the fuzzy rule and decision tree provide accuracy level are 91.86% and 92.39%. As a conclusion, this study showed that the flow experience could be measured with the high accuracy level. In the context of e-learning, it can be used by e-learning to provide an adaptation. Appropriate adaptation is expected can keep the psychological condition of the students in optimal state.

1. Introduction

Implementation of e-learning model has provided a new way for learning access. Even though, this learning process has several issues related to situation, needs, and condition of the user. From these points, there are still limited development of e-learning model with consideration of learner psychological aspect [1]. The previous studies are a lot of emphasis on the learners' experience in terms of ease of use and usefulness in e-learning [2]. Even though the psychological aspect significantly affects learners interest to the learning process [3]. Recently, there has been a growing number of studies that involve psychological experience in e-learning model.

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The most common psychological experiences in the learning process are anxiety, boredom, and optimal that is felt by the learners. These three conditions are based on the flow theory that explains learner emotional, cognitive, and motivation conditions. The flow state is obtained when learner skills (experience, knowledge, cognitive ability) are on par with the given challenges or problems. Meanwhile, anxiety is experienced when learner skills are lower than the presented challenges. On the contrary, if the learner skills are higher than the given problems, they will feel bored [4]. Thus, measurement of the balance between challenges and skills is one of essential focus in flow theory.

Several studies have been conducted to measure and identify of flow states. The identifications of flow in general are usually survey-based data derived from using statements and various scales to rate the statements [5]. They used factors that are considered to influence flow. Some tools have been implemented such as experience sampling method, the flow states scales [6], and psycho psychological measures [7]. In other study, variables of flow are combined with technology acceptance model in order to investigate the impact of learning material presentation to student intensity of learning. These flow variables are measured after student finishing an online learning session. Other studies show that the flow identifications are done in face to face situation. Similar with previous studies, flow variables are measured after completion the class.

Identification of flow experience from the existing studies have explained that the flow is measured by conducting several surveys and delivering questionnaires after a learning process, included in face to face and in online learning situation. Some studies got the effective results, but is not efficient, consuming time and cost. On the other hand, it cannot capture the student psychological condition naturally, during interaction with the e-learning. Therefore, this study aims to identify flow experience by using attributes and parameters of student learning behavior during interaction with the e-learning. These parameters are used to infer the flow states that consists of flow, boredom, and anxiety. In this study, the identification of the flow states used rough set and two methods in machine learning approach as the comparison. Rough set is one of efficient method to solve the uncertainty like psychological experience. Whereas, machine learning approach many used as a powerful tool in knowledge data discovery. This paper follows several sections: Introduction (Section 1), Theoretical Background (Section 2), Research Method (Section 3), Results and Discussion (Section 4), and Conclusion (Section 5).

2. Theoretical background

This section described some theoretical background that support in this study. The theory in this section focus on flow theory and rough set.

2.1. Flow theory

The flow theory is first presented by Mihaly Csikszentmihalyi who use the term 'flow' to represent the optimal experience of a person to focus on his involvement in activity [4]. A person in flow state is at a high concentration level, with no room for other thoughts. Even though the flow is built from various complex variables, but two of the most important variables are skill and challenge [8]. Therefore, flow experience often described by involving these two variables. Three conditions explained in flow theory are flow state, anxiety, and boredom. The flow state is obtained when a person's skills are on par with the given challenges or problems. Meanwhile, anxiety is experienced when the skills are lower than the given challenges. On the contrary, if the skills are higher than the given problems, the person will feel bored. These states can be described in Figure 1. If flow can be identified, it is expected to distinguish the lower and upper student. Inducing flow to the learning can give advantages to increase the lower successful [9].

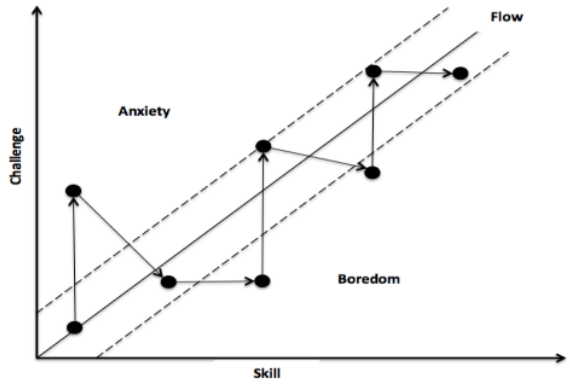

Figure 1. Balance skill-challenge in flow states.

2.2. Rough set

Rough set theory has been introduced by a Polish computer scientist Zdzisław Pawlak. It is a formal approximation of a crisp set in terms of a pair of sets which give the lower and the upper approximation of the original set [10]. The main goal of the rough set analysis is induction of learning approximations of concepts. Rough sets constitute a sound basis for knowledge data discovery. It offers mathematical tools to discover patterns hidden in data. Rough set can be used for feature selection, feature extraction, data reduction, decision rule generation, and pattern extraction [11]. There are some powerful about rough set method, such as: (i) It can identify partial or total dependencies in data; (ii) It can eliminate redundant data; (iii) It gives approach to null values, missing data, dynamic data.

The rough set, generally is separated into information systems, indiscernibility matrices, approximation, and generating rules. It can be figure out as an information systems I=(U,Ω,Vq,fq) as follows [10,12]:

U : Universe set;

Ω : Set of attributes;

Ω = $C \cup D$, C is a finite set of condition attributes and D is a finite set of decision attributes;

for each $q \in \Omega$, Vq is called the domain of q;

f : an information function $fq : U \rightarrow Vq$;

3. Research method

This study follows some steps to reach the objective of the research. First step begins with the data collection. Each step implemented methods, tools, and supporting references.

3.1. Data collection and attributes

In this research, data is obtained from IT Risk Management subject that involving approximately 92 students from different classes. Two topics in this lecture were tried to obtain training and testing data. Flow states are measured and labelled as optimal conditions (flow), boredom, and anxiety. While intensity learning (frequency of accessing material, duration of accessing material), assessment score, and duration of assessment completion are attributes stored on log server [13].

3.2. Rough set and machine learning methods

Data set from the previous step was implemented using rough set and two machine learning approach (Decision tree and Fuzzy rule). Rough set, decision tree, fuzzy rules have similar form of the results. They generated the rules as the model for classification. Decision tree and fuzzy rule were implemented using Knime application tools. The validation used k-fold cross validation with k=4. The evaluation

models are measured using accuracy level and reliability value. Flow design of decision tree and fuzzy rule using Knime is presented in Figure 2. The design of decision tree and fuzzy rule follows several steps: (i) input data set; (ii) normalize the data set; (iii) identify outlier data and remove it; (iv) validate data using k-fold cross to separate data into data training and data testing; (v) conduct data learning and generate rules; (vi) conduct data testing; (vii) determine confusion matrices and reliability value.

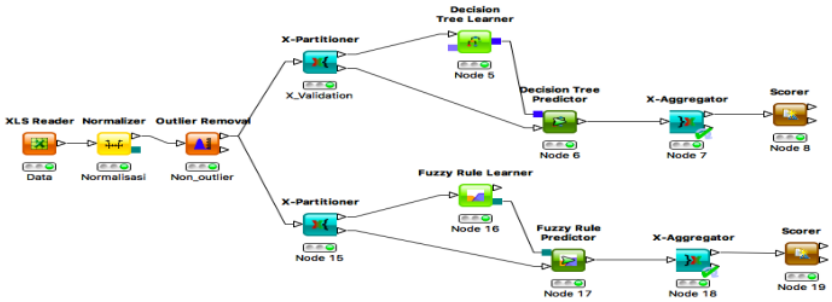

Figure 2. Flow design of decision tree and fuzzy rule using Knime.

Rough set has been implemented into four types of classified category as presented in Table 1.

Table 1. Type of attributes category.

Number of category	Category
2	High: Data ≥ Mean Low: Data < Mean
3	High: Data > Mean + SD Medium: Mean - SD ≤ Data ≤ Mean + SD Low: Data < Mean - SD
4	Very High: Data ≥ Q3 High: Q2 ≤ Data < Q3 Medium: Q1 ≤ Data < Q2 Low: Data < Q1
5	Very High: Data ≥ Mean + 1.8SD High: Mean + 0.6SD ≤ Data < Mean + 1.8SD Medium: Mean - 0.6SD ≤ Data < Mean + 0.6SD Low: Mean – 1.8SD ≤ Data < Mean – 0.6SD Very Low: Data < Mean - 1.8SD

4. Results and discussion

This section presents the result and discussion of flow state data processing based on prediction result using rough set and machine learning approach (decision tree and fuzzy rule).

4.1. Result of identifying flow using rough set

Based experiment involving 92 data sets using rough set, they are different results for each category. The distinguish of the results included in number of data reduction, number of generated rules, and accuracy level. The summary of the results of identifying flow experience using rough set is showed in Table 2. Based on the results, category 2 gives the largest number of data reduction. The original data set is reduced up to 39 data. It generated four rules for prediction, with accuracy level is 74.74%.

According to rough set theory, these results are possible, since the method has ability to eliminate data that can be ignored in decision making. Based on this view the results have shown that rough set provided the simple way for prediction. In the contrast, category 4 produced 7 eliminated data, 61 generated rules, and the highest accuracy level, 92.92%. In the glance, it is the best model for prediction. But, it should be considered the other of the result parameters such as number of generated rules. Even though it gives the highest accuracy, but it also gives the highest generated rule. Comparing with other results, it is too much that can influence to computing process. As the moderate results category 3 and category 5 give similar value in accuracy level. Category 3 has 15 eliminated data, 28 generated rules, and 84.84% in accuracy. Meanwhile, category 5 got 13 eliminated data, 15 generated rules, and 86.86% in accuracy. These different results can provide choices in making decisions. Basically, approaching different considerations will also give different decisions. If computational complexity is not an issue, perhaps the highest accuracy model can be used. Meanwhile, if it relies on the principle of simplicity, a model with a small number of rules that can be taken, although still taking into account the acceptable level of accuracy.

Table 2. Identifying flow using rough set.

Number of Category	**Number of Reduced Data**	***Number of Generated Rule***	**Accuracy**
2	39	4	7.4.74%
3	15	28	84.84%
4	7	61	92.92%
5	13	15	86.86%

4.2. Result of identifying flow machine learning approach

As the comparison, the machine methods used in this study were decision tree and fuzzy rule. Accuracy comparison of two machine learning approach used in this study based on confusion matrices is shown in Table 3 and Table 4.

Table 3. Identifying flow using Decision Tree.

Flow State	**Anxiety**	***Boredom***	**Flow**
Anxiety	69	1	2
Boredom	0	14	0
Flow	3	1	2
Accuracy	**92.4%**		
Cohen's Kappa	**0.788**		

Table 4. Identifying flow using fuzzy rule.

Flow State	**Anxiety**	***Boredom***	**Flow**
Anxiety	68	0	1
Boredom	3	9	0
Flow	3	0	2
Accuracy	**91.86%**		
Cohen's Kappa	**0.703**		

Decision tree method had the highest accuracy of 92.39% with Cohen's Kappa value of 0.788, which shows that this method generated an excellent prediction with moderately high reliability. Meanwhile, model accuracy using fuzzy rule method was 91.86% with reliability value of 0.703. Both of the methods have showed that the measurement models are valid and reliable.

Similar with the rough set, decision tree and fuzzy rule produced rules as the model for prediction. These approaches had the high score in accuracy with the allowed reliability level. However, they have

challenge in complexity during computing process. Yet, this is not a problem in decision making as long as things become challenging can still be accepted.

5. Conclusion

The identifying flow experience using rough sets and machine learning approach has been presented in this study. By implementation of three approaches, this study showed that the flow experience can be measured with the high accuracy level with good reliability. The rough sets give the highest accuracy, even though it generates too many rules. Balancing the number of criteria, number of generated rule, number of eliminated data, and level of accuracy can be considered for decision making.

For the future works, since the Rough Sets using category for the attributes, in the next research, it is good to consider type of distribution during classification criteria/attributes.

Acknowledgments

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