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# The 1st International Conference on Control, Optimization and Mathematical Engineering 2021 (ICOCOME 2021)

**Bandung, Indonesia** • 17 November 2021

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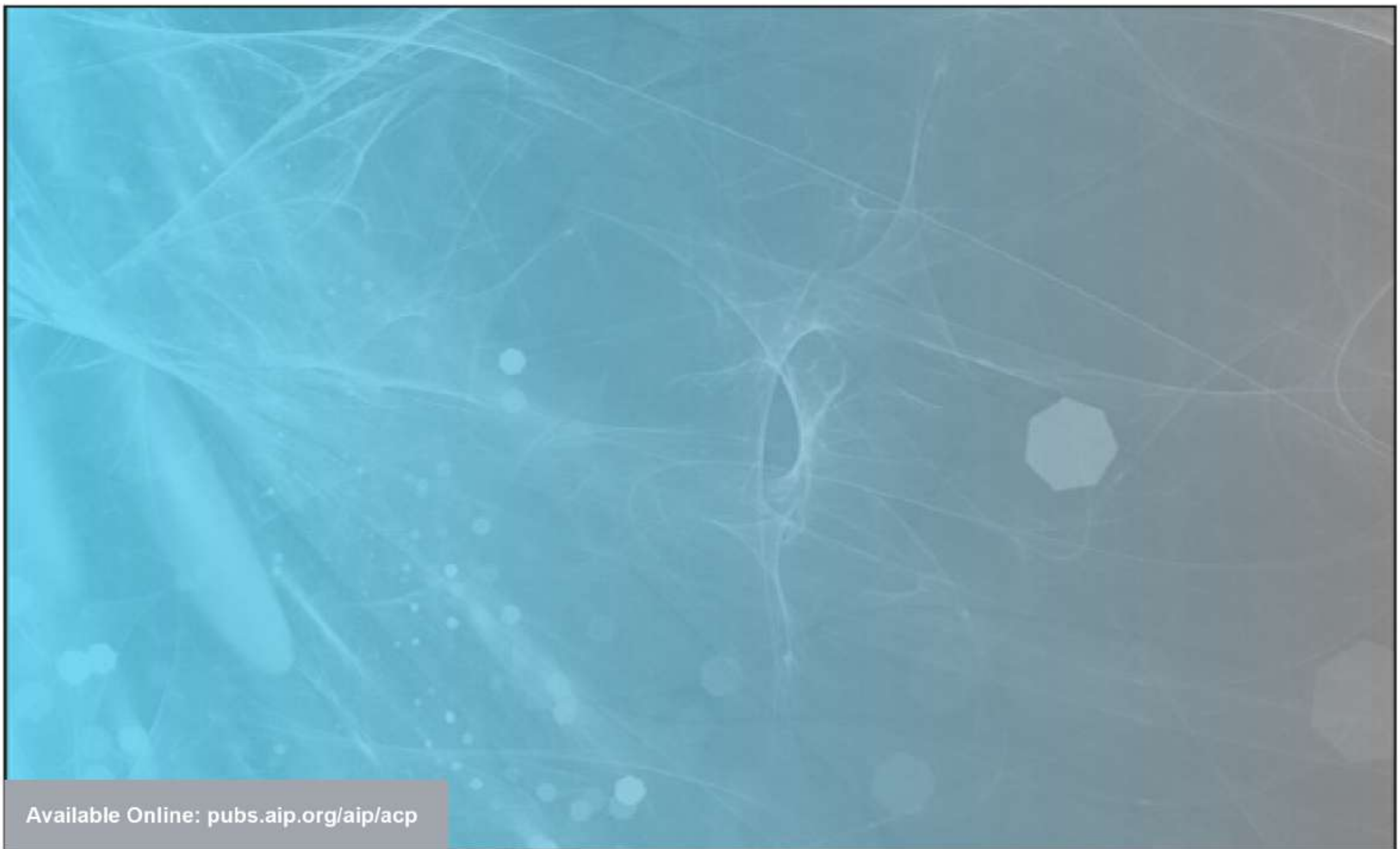

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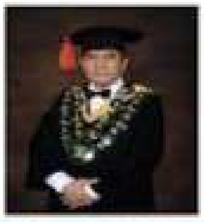

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RESEARCH ARTICLE | OCTOBER 18 2024

# Preface: The 1st International Conference on Control, Optimization and Mathematical Engineering 2021 (ICOCOME 2021)

*AIP Conf. Proc.* 2867, 010001 (2024)

https://doi.org/10.1063/12.0026528

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# Preface: The 1st International Conference on Control, Optimization and Mathematical Engineering 2021 (ICOCOME 2021)

Welcome to the **1st International Conference on Control, Optimization and Mathematical Engineering 2021 (ICOCOME 2021), 17 November 2021**, West Java, Indonesia. The International Conference on Control, Optimization and Mathematical Engineering 2021 (ICoCOME 2021) is an excellent communication forum for discussion and exchange of ideas for researchers and practitioners in the fields of control, optimization, and Engineering Mathematics from around the world. This conference is organized by the Department of Mathematics, Faculty of Mathematics and Natural Science Universitas Padjadjaran (Unpad) in collaboration with the Indonesian Mathematical Society (IndoMS), Indonesian Operations Research Association (IORA), and Management Science / Operations Research Society of Malaysia (MSORSM), and supported by several universities in the world, Research Collaborations Community (RCC), and several Industrial Institutions.

The conference included 6 plenary speakers in control, optimization, and mathematical engineering. We invite speakers from various uinversity, such as Prof. Dr. Sundarapandian Vaidyanathan as Research and Development in Vel Tech University, India. Assoc. Prof. Ts. Dr. Adibah Shuib, FIMA as lecturer from Universiti Teknologi MARA (UiTM), Malaysia. Prof. Dr. Saleh Mobayen as Professor from University of Zanjan, Iran & National Yunlin University of Science and Technology, Taiwan. Prof. Dr. Sudradjat Supian as Padjadjaran University, Indonesia. Prof. Dr. M. Yusuf Waziri as Professor from Bayero University Kano, Nigeria and Prof. Shahjahan Khan, Ph.D as Professor from University of Southern Queensland, Australia.

We are also thankfull to AIP Proceeding for the support which has led to the smooth conduction of the conference.

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RESEARCH ARTICLE | OCTOBER 18 2024

# Event log analytics to correlate the academic achievements of students using low-cost high-utility sequential pattern algorithm

Ridho Gunawan

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During the Covid-19 pandemic, almost all learning is done online through learning management system. All activities carried out in the learning management system are recorded in the event log. Only looking for the sequence of activities carried out by the learner is not an enough analysis of the event log. It is also necessary to see whether the activities carried out are effective. Analysis of event logs can be used to improve the quality of the learning process. The method used to get an effective event log activity is to develop a sequential pattern method, which is to find a sequence of activities that is low-cost while getting high utility. Low cost means that students use as little time as possible to complete an activity, while high utility means that students get maximum value learning outcomes. Learning outcomes can be in the form of quizzes or assignments. Measurement of the effectiveness of the pattern obtained is in terms of looking at the correlation between cost and utility of the pattern formed. This method is applied to analyse the event log obtained from the Moodle learning management system for one course. The experimental results show learning patterns in which they show

effective patterns and can obtain patterns that can improve learning optimization. Searching for low-cost high-utility patterns in the event log of the learning management system is one effective way to improve learning performance.

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# Event Log Analytics to Correlate the Academic Achievements of Students using Low-Cost High-Utility Sequential Pattern Algorithm

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**Abstract.** During the Covid-19 pandemic, almost all learning is done online through learning management system. All activities carried out in the learning management system are recorded in the event log. Only looking for the sequence of activities carried out by the learner is not an enough analysis of the event log. It is also necessary to see whether the activities carried out are effective. Analysis of event logs can be used to improve the quality of the learning process. The method used to get an effective event log activity is to develop a sequential pattern method, which is to find a sequence of activities that is low-cost while getting high utility. Low cost means that students use as little time as possible to complete an activity, while high utility means that students get maximum value learning outcomes. Learning outcomes can be in the form of quizzes or assignments. Measurement of the effectiveness of the pattern obtained is in terms of looking at the correlation between cost and utility of the pattern formed. This method is applied to analyse the event log obtained from the Moodle learning management system for one course. The experimental results show learning patterns in which they show effective patterns and can obtain patterns that can improve learning optimization. Searching for low-cost high-utility patterns in the event log of the learning management system is one effective way to improve learning performance.

**Keywords:** Sequential Pattern Algorithm, Event Log Analytics, Learning Management System

## INTRODUCTION

The ongoing COVID-19 pandemic has resulted in changes in the learning process. Learning activities that previously could be done face-to-face have now changed to being done virtually [1]. Activities such as the delivery of learning material, the assessment process and the discussion process that were initially carried out face-to-face, must be changed virtually. This of course is not easy. Lecturers still want these activities to be carried out directly, but the pandemic period forces learning activities to be carried out virtually. Like it or not, the learning process must be presented virtually. One way that can be done to change learning activities from face-to-face to virtual is to utilize the Learning Management System (LMS). In the pre-pandemic period, the use of LMS was not widespread, even though LMS was available but had not been used optimally, both in terms of content and activities conveyed in the LMS. At that time, LMS was only used to upload teaching materials or only to create and do quiz questions. But this pandemic forces the teaching and learning process to be carried out using LMS as a whole. All learning processes that are carried out offline are 'depicted' to be delivered to the LMS [2].

When designing a learning session, it will always be guided by the learning outcomes of the course. When lecturers design learning scenarios, they will imagine doing learning activities in a classroom. For example, the learning scenario begins with students making attendance, lecturers provide material, lecturers give assignments, students discuss in groups and ends with lecturers giving assessments. The learning process can take place virtually through activities designed in a virtual space. The lecturer hopes that all scenarios are carried out by students, so that learning outcomes can be achieved through this process. Even without the physical presence of the lecturer, learning activities can still be monitored [3].

Activity monitoring on the LMS page can be seen in the event log of the LMS. The event log records all activities carried out by each learner. The event log of a course records the activity of the learner (participant), when the activity was carried out, to what activity and what actions were carried out on each of these activities. For example, a course "A" has many topics. Each topic will have many activities. For example, the activity you have is a quiz. In each quiz there will be many events that may occur, including views. Are the activities on the LMS recorded in the event log monitored by the lecturer as the lecturer monitored activities face-to-face?

An analysis of the activities on the LMS page recorded in the event log needs to be done to see how far the learners are involved in the LMS page and can be used for the process of improving the quality of learning [4]. Therefore, it is necessary to carry out a data mining process so that knowledge from the LMS can be obtained. Not only seeing the order made by users, frequently visited pages, but also seeing the effectiveness of using the LMS. Analysis of the effectiveness of the LMS can also be used by lecturers to design effective activities. The hope is that students can carry out activities on the LMS page as efficiently as possible. The costs incurred are minimal, which can be seen from the time used to access each existing activity but obtain maximum assessment results.

The purpose of this research is to get an interesting pattern from the event log, not just a sequence of activities, but to get an efficient sequential pattern. The time to do activities is minimal but produces the maximum possible outcome. The method that will be used to obtain the pattern is low-cost high-utility pattern mining. The benefit of this research is that it helps learners to improve the quality of their learning outcomes and is used by lecturers to design effective activities.

The rest of this paper is organized as follows: Related work is briefly reviewed in Section 2. The methodology for low-cost-high utility item sets mining is presented in Section 3. Experimental design, result, and analysis are provided in Section 4. The paper is concluded in Section 5.

## RELATED WORK

Various methods have been used to analyse learning activities in LMS. In general, the method used to conduct the analysis aims to obtain a pattern of the sequence of activities carried out by the learner which is then used to develop a learning model [5]-[6]. Analysis of patterns that lead to learning outcomes has also been carried out in [7]-[8]. The level of students' understanding of the built process model can be obtained using the mining process by applying the complexity matrix (CM) [9].

However, these methods have not considered the effectiveness of the teaching and learning process. Although activity patterns and predictive outcomes can be obtained, it cannot be calculated how effective the activities carried out by the learner are. To be able to see how effective the activities carried out by learners are, the analysis of activities recorded on the LMS must see how long it takes for each meeting and review the assessment values obtained for each meeting. The analytical method used is to develop frequent sequential pattern mining by adding utility values. It is hoped that a low-cost high-utility sequential pattern can be obtained to improve the quality of the pattern obtained.

To get a low-cost high-utility sequential pattern (LCHUSP) it starts with looking for patterns in sequential data, high-utility sequential patterns and then low-cost high-utility sequential patterns. Sequential pattern mining has been developed for a wide variety of applications such as web click-stream analysis, medical data, biological data, and e-learning data. Pattern search from sequential data is analogous to searching for frequent data [10]–[12] . Sequential pattern mining algorithms can be categorized into two, namely a horizontal database format approach (as in General Sequential Pattern (GSP) [11], Prefix Span [13], Copan [14]) and a vertical approach (as in SPADE (Sequential Pattern Discovery using Equivalence Class) [15] and SPAM [16]). Fradkin and Mörchen [17] developed a pruning algorithm so that the pattern search process does not take a long time, especially for infrequent candidates. Fournier-Viger et al. [16] has provided the results of a comprehensive survey of various algorithms for sequential pattern search.

The expansion of the search for sequential patterns carried out is not only paying attention to frequent and infrequent, but also paying attention to utility measurements. Zhang et al. [18] revealed the concept of high-utility sequential pattern mining (HUSPM), which is a search for frequent sequential patterns while also having high utility. The HUSPM input is the minimum utility and database that has been sequenced, while the HUSPM output is a set of high-utility sequences that have a utility value that is higher than the specified minimum utility. HUSPM was developed using the basic algorithm of sequential pattern based on general sequential pattern and pattern growth approach. Le et al. [19] made improvements to HUSPM using the SPAM approach given USpan (Utility Sequential

PAtterN). Wang et al. [20] improved USpan by doing a breadth first search to reduce the number of candidates. In addition, Alkan et al. [21] also made improvements in the pruning process using Cumulated Rest of Match (CRoM) and High Utility Sequential Pattern Extraction (HuspExt) so that the search for high utility patterns from large scale datasets is more efficient [22]. However, although high-utility sequential pattern mining has been applied in several cases, especially in shopping carts, the attention is only on utility values. The cost value has not been considered, so the pattern obtained cannot be assessed whether the pattern is indeed an attractive pattern.

Dalmas et al. [23] has conducted a sequential pattern search process based on the activity-cost event log. The analysis was carried out on the real-life healthcare event log to see the pattern of the course of treatment carried out by a patient. In addition to the order of treatment carried out, the costs that must be incurred in each treatment series are also considered. The algorithm developed is named TWINCLE (Time-WINdow, Cost and LEngth constrained sequential rule mining). TWINCLE can be used as a reference to find out sequential patterns that consider costs, but utility is not a consideration.

Fournier-Viger et al. [24] has conducted a search for a low-cost high-utility pattern on sequential data. There are 3 set scenarios, namely (1) CEPB algorithm for mining cost-efficient patterns in sequences with binary utility information and cost values. The stored utility is in the form of binary, while the cost value can be a numeric value. (2) CEPN algorithm for mining sequence with cost and numerical utility. What distinguishes it from CEPB is the value of utility, which uses numeric values. (3) CorCEPB algorithm to see the correlation between cost and binary utility. To see the performance of the algorithm, dummy datasets are used, namely Bible, BMS, SIGN and FIFA derived from SPMF, the dataset is made to have cost and utility values. Analysis was also carried out on e-learning data obtained from the Deeds e-learning environment [8].

## METHODOLOGY

Our proposed method consists of four processes, namely: data collection, pre-processing phase, sequential pattern mining using SPADE (Sequential Pattern Discovery using Equivalence Class) algorithm, sequential pattern mining with low-cost high-utility (LCHUSP) algorithm and the last process is pattern evaluation.

### Data Collection

The dataset used consists of two groups, namely data containing the sequence of activities carried out during the learning process and quiz scores obtained for one meeting. Activity sequence data was obtained from the Moodle LMS log for one course and one learning meeting. The quiz scores are obtained from scores obtained at an exam for each participant. To get data from Moodle LMS, the first thing is to select the course to be analysed, then select the Course Administration menu, after that select Reports and the last is select Logs. Logs can be downloaded by course name, participants, days, activities, actions, sources and by events. Detailed information about log contents can be found in the Moodle documentation (https://docs.moodle.org/311/en/Logs).

### Pre-processing Phase

The pre-processing phase is used to prepare the data obtained from the Moodle LMS so that it can be processed using the SPADE algorithm and the LCHU algorithm. The pre-processing stage is changing the log data obtained from the Moodle LMS into two data sets, namely a dataset containing data sequences based on learner activities and a dataset containing sequence data with cost and utility.

The steps taken are:

First download the desired data criteria. The data obtained from the Moodle LMS log has attributes, namely time, user full name, affected user, event context, component, event name, description, origin, and IP address. An example of the log data obtained can be seen in Table 1.

Create a sequential dataset from log data. Each participant will have a sequence of activities. So, the number of records in the dataset will be equal to the number of participants who accessed the session.

Table 2 is an example of sequential data. The limit between an activity is marked with -1 while the end limit for a sequence is marked with -2.

Creating a sequential dataset that has been equipped with cost values for each data activity in the sequential and utility values for each sequential data. The cost value for each activity is obtained from the access time made by the user to certain activities. While the utility value is the result of the quiz obtained by each participant. The results of sequential data that have been completed with cost and utility values can be seen in the Table 3. The cost value for each activity is delimited by a [..] sign, the boundary between activities uses -1, while the end of a sequence is marked with -2. The utility value is indicated by the word *Utility* which is placed at the end of each sequence.

**TABLE 1.** Example of log data.

| No | Log |
|---|---|
| 1 | 23/08/21, 15:14,"195314084 AMADEUS PALI HAMAPATI",-,"Course: Analisis dan Strategi Algoritma D (TI I/2021/2022)", System,"Course viewed", "The user with id '10306' viewed the course with id '19323'.",web,180.246.173.44 |
| 2 | 23/08/21, 15:04,"195314147 ANDREAS SITINJAK",-,"Course: Analisis dan Strategi Algoritma D (TI I/2021/2022)", System,"Course viewed", "The user with id '10369' viewed the course with id '19323'.",web,116.206.31.85 |

**TABLE 2.** Sequence data.

| No | Sequence data |
|---|---|
| 1 | Course_viewed_19323. -1 Course_viewed_19323. -1 Course_viewed_19323. -1 Course_viewed_19323. -1 Course_module_viewed/File/321011. -1 Course_module_viewed/URL/321366. -1 Course_module_viewed/URL/321366. -1 Course_viewed_19323. -1 Course_module_viewed/Quiz/330479. -1 Course_viewed_19323. -1 Quiz_attempt_viewed/330479. -1 Quiz_attempt_viewed/330479. -1 Course_module_viewed/System/_330479 -1 Course_viewed_19323. -1 -2 |

**TABLE 3.** Sequence data with cost and utility.

| No | Sequence data with cost and utility |
|---|---|
| 1 | Course viewed 19323.[10] -1 Course viewed 19323.[5] -1 Courseviewed19323.[2] -1 Courseviewed19323.[1] -1 Coursemoduleviewed/File/321011.[2] - Coursemoduleviewed/URL/321366. [0] -1 Coursemoduleviewed/URL/321366. [5] -1 Courseviewed19323.[1] -1 Coursemoduleviewed/Quiz/330479. [1] -1 Courseviewed19323.[4] -1 Quizattemptviewed330479.[0] -1 Quizattemptviewed330479.[4] -1 Coursemoduleviewed/System/d9971.[1] -1 Courseviewed9323.[114] -1 -2 Utility:80 |

## Sequential Pattern Mining with SPADE

The sequential pattern mining algorithm used is the SPADE (Sequential Pattern Discovery using Equivalence Class) algorithm. SPADE performs a sequential pattern search process using vertical data format [15]. The pseudo-code of SPADE is shown in Algorithm 1). Function Enumerate-Frequent-Seq is shown in Algorithm 1.

## Sequential Pattern Mining with Low-Cost High-Utility (LCHUSP) Algorithm

To get a low-cost high-utility pattern, the CEPN algorithm is used [24]. Input for this algorithm is sequence with cost and numeric utility. Pseudo-code of CEPN is shown in Algorithm 3) and Algorithm 4).

**Algorithm 1.** SPADE (D, minsup)

**Input**: A sequence databases D, minimum support threshold *minsup*
**Output:** The complete set of sequential patterns
$F_1$: frequent items or 1-sequences;
$F_2$: frequent 2-sequences;
$\varepsilon =$ equivalence classes $[X]$;
**for all** $[X] \in \varepsilon$ **do**
  Enumerate-Frequent-Seq $(X)$ ;
**end for**

**Algorithm 2.** Enumerate-Frequent-Seq (D)

**for all** atoms $A_i \in S$ **do**
  $T_i = 0$;
  **for all** atoms $A_j \in S, with\ j \geq i$ **do**
    $R = A_i\ v\ A_j$;
    $\boldsymbol{if}\ (Prune(R) == FALSE)\ \boldsymbol{then}$
      $L\ (R) = L(A_i) \cap L(A_j)$;
      $\boldsymbol{if}\ \delta(R) \geq min\_sup\ \ \boldsymbol{then}$
        $T_i = T_i \cup \{R\}; F_{|R|} = F_{|R|} \cup \{R\}$;
      ***end if***
    ***end if***
  **end for**
  $\boldsymbol{if}\ (Depth - First - Search)\ \boldsymbol{then}$
    $Enumerate - Frequent - Seq(T_i)$;
  ***end if***
**end for**
$\boldsymbol{if}\ (Depth - First - Search)\ \boldsymbol{then}$
  **for all** $T_I\ \neq 0$ **do**
    $Enumerate - Frequent - Seq(T_i)$;
  **end for**
***end if***

**Algorithm 3.** CEPN (*D, minsup, maxcost*)

**Input:** A sequence databases with numeric utility *D*, minimum support threshold *minsup*, maximum cost *maxcost*, the projected database list *pdList*
**Output:** the low-cost high-utility patterns
**Read** the *D* once to calculate the support, average cost and ascending (ASC) for each event:
$endPost\ \leftarrow 0$;
**for** each event $a$ **do**
  $\boldsymbol{if}\ sup(a) \geq minsup\ \ \boldsymbol{then}$
    $\boldsymbol{if}\ ac(a)\ \leq maxcost\ \ \boldsymbol{then}$
      $Calculate\ tF(a)$;

```
            Save (a);
        end if
        if (asc(a) ≤ maxcost) then
            CreateProjectedDatabase(a, sumList, pdList, endPos);
        end if
        else
            Remove event a from the database
    end if
  end for
Search(0, endPos − 1, sumList, pdList)
```

**Algorithm 4.** Search ()

```
Input: two position preEndPos and preStartPos of the summary list, the summary list
sumList, the projected database list pdList.
Output: the low-cost high-utility having p as prefix
for i ← preEndPos to preStartPos do
    p ← sumList[i].pattern;
    PD_p ← project databases of p stored in the pdList;
    Scan PD_p to co calculate the support, average cost and ASC (or AMSC)of p ∪
    a for each event a appearing in PD_p
    for each event a ∈ PD_p do
      if sup(a) ≥ minsup then
          if act(p ∪ a) ≤ maxcost then
                Calculate tF(p ∪ a);
                Save (p ∪ a);
          end if
          if (asc(p ∪ a) ≤ maxcost) then
              CreateProjectedDatabase(p ∪ a, sumList, pdList, endPos);
          end if
      end if
    end for
    Search(0, endPos − 1, sumList, pdList)
End for
```

## Pattern Evaluation

The evaluation of the pattern carried out is to compare the number of patterns obtained from SPADE and LCHUSP. The purpose of comparing the number of patterns obtained is to see whether the addition of cost and utility constraints will affect the number of patterns obtained. Pattern evaluation is also carried out by comparing the results of the itemset pattern formed between those generated by SPADE and LCHUSP. Looking at the pattern obtained, is there any difference in the pattern obtained between SPADE and LCHUSP.

# RESULTS AND DISCUSSION

## Experimental Setup

All algorithms are implemented in Java, executed on a PC with AMD Ryzen 7 2700 Eight-Core Processor, 3200 MHz, 8 cores, 16 logical processors and 16.0 GB of RAM, running 64-bit Windows 10. There are 2 software used, software used for the pre-processing phase to process datasets from LMS logs into integrated datasets and software for implementing low-cost high-utility pattern search algorithms. The software used in the pre-processing stage uses

R, while the pattern search algorithm is entirely implemented using the Java language. Implementation of the algorithms is based on SPMF, the open-source data mining library [25].

To get a sequential pattern from SPADE, experiments were carried out using various minimum support values, 40%, 50%, 60%, 70%, 80%, and 90\%. The minimum utility values used to obtain cost-low high-utility sequential patterns from CEPN *minutil* is 70, and maximal cost *maxcost* is 60. The minimum utility represents the minimum value obtained by the participant, while the maximum cost is the maximum time it takes to complete a sequence. The number of patterns will be compared between those obtained using SPADE and CEPN. In addition, observations were made on the patterns obtained from the two algorithms, to see the improvement in the quality of the patterns obtained.

### *Number of Patterns*

The number of patterns obtained from SPADE and LCHUSP can be seen in FIGURE 1. The number of patterns from SPADE is always more than LCHUSP, the number of patterns obtained is inversely proportional to the specified minimum support. The higher the minimum support value, the less the number of patterns formed. The SPADE pattern is more than LCHUSP because SPADE does not consider the value of cost and utility, meaning that the pattern obtained assumes that the cost value for each item is the same. Whereas in LCHUSP the cost value of each item is taken into consideration, when added up the value should not be greater than the maximum cost limit set.

### *Patterns.*

Sequential patterns from SPADE can be seen in Table 4. Patterns are displayed according to support values. Low-cost high-utility sequential pattern can be seen in Table 5. Patterns are displayed according to utility values.

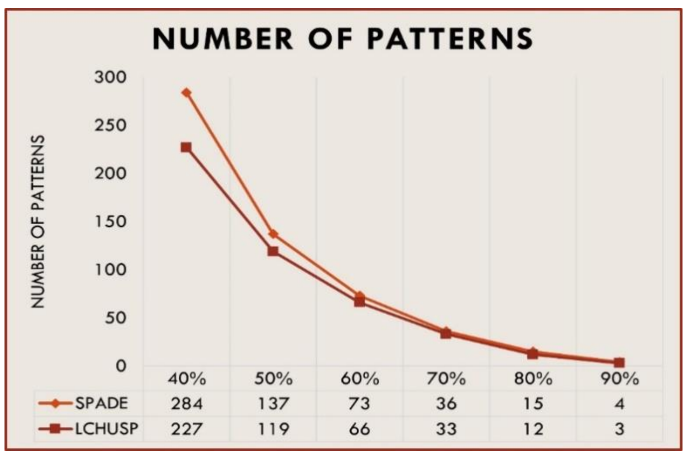


**FIGURE 1.** Number of Patterns SPADE vs LCHUSP.

**TABLE 4.** Sequential Pattern.

| No | Pattern | Support Count |
|---|---|---|
| 1 | Quiz attempt viewed/330479. | 40 |
| 2 | Course viewed/ 19323. | 35 |
| 3 | Course viewed/ 19323. ; Course viewed/ 19323. | 35 |
| 4 | Course viewed/ 19323. ; Course viewed/ 19323. ; Course viewed/ 19323. | 33 |
| 5 | Course viewed/ 19323. ; Course viewed/ 19323. ; Course viewed/ 19323. ; Course viewed/ 19323. | 33 |
| 6 | Course viewed/ 19323. ; Course viewed/ 19323. ; Course viewed/ 19323. ; | 31 |

| | | |
|---|---|---|
| | Course viewed/ 19323. ; Course viewed/ 19323. | |
| 7 | Quiz attempt viewed/330479. ; Quiz attempt viewed/330479. | 30 |
| 8 | Course viewed/ 19323. ; Quiz attempt viewed/330479. | 30 |
| 9 | Course viewed/ 19323. ; Quiz attempt viewed/330479. ; Quiz attempt viewed/330479. | 30 |
| 10 | Course viewed/ 19323. ; Course viewed/ 19323. ; Quiz attempt viewed/330479. | 29 |
| 11 | Course viewed/ 19323. ; Course viewed/ 19323. ; Quiz attempt viewed/330479.; Quiz attempt viewed/330479. | 29 |
| 12 | Course module viewed/URL/321366. | 28 |
| 13 | Quiz attempt viewed/330479. ; Quiz attempt viewed/330479. ; Quiz attempt viewed/330479. | 28 |
| 14 | Course viewed/ 19323. ; Course module viewed/URL/321366. | 28 |
| 15 | Course viewed/ 19323. ; Quiz attempt viewed/330479.; Quiz attempt viewed/330479. | 28 |

**TABLE 5.** Low-cost high-utility sequential patterns

| No | Patterns | Utility | Support | Average Cost |
|---|---|---|---|---|
| 1 | Quiz attempt viewed/330479. ; Quiz attempt viewed/330479. ; Quiz attempt viewed/330479. | 83.857 | 28 | 3.107 |
| 2 | Course viewed/ 19323. ; Quiz attempt viewed/330479. ; Quiz attempt viewed/330479. ; Quiz attempt viewed/330479. | 83.857 | 28 | 11.964 |
| 3 | Course viewed/ 19323. ; Quiz attempt viewed/330479. | 81.733 | 30 | 9.6 |
| 4 | Quiz attempt viewed/330479. ; Quiz attempt viewed/330479. | 81.733 | 30 | 2.133 |
| 5 | Course viewed/ 19323. ; Quiz attempt viewed/330479. ; Quiz attempt viewed/330479. | 81.733 | 30 | 10.767 |
| 6 | Course viewed/ 19323. ; Course viewed/ 19323. ; Quiz attempt viewed/330479. | 81.103 | 29 | 18 |
| 7 | Course viewed/ 19323. ; Course viewed/ 19323. ; Quiz attempt viewed/330479. | 81.103 | 29 | 19.172 |
| 8 | Course viewed/ 19323. ; Course module viewed/URL/321366. | 77.429 | 28 | 21.107 |
| 9 | Course viewed/ 19323. ; Course viewed/ 19323. ; Course viewed/ 19323. ; Course viewed/ 19323. ; Course viewed/ 19323. | 73.29 | 31 | 38.065 |
| 10 | Course viewed/ 19323. ; Course viewed/ 19323. ; Course viewed/ 19323. | 71.273 | 33 | 21.545 |
| 11 | Course viewed/ 19323. ; Course viewed/ 19323. ; Course viewed/ 19323. | 71.273 | 33 | 30.091 |
| 12 | Course viewed/ 19323. ; Course viewed/ 19323. | 70.057 | 35 | 33.371 |

## CONCLUSION

From our experiments, the addition of cost and utility values to sequential data can produce a more meaningful pattern than using only sequential data. High support does not always mean that it will produce high utility. Sequential patterns using minimal cost and maximum utility can be used to design learning materials so that the learning process becomes more qualified. Learners can use efficient patterns with minimal costs but get maximum outcomes from the learning process.

For the future, it is necessary to experiment with all sessions in one course so that the results of the analysis can be more comprehensive. Application of the concept of low-cost high-utility sequence pattern is applied to other fields, such as e-commerce, transportation, gene sequence analysis, treatment process, etc.

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