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List of Authors: Anita Qoiriah, Yuni Yamasari, Asmunin Asmunin, Andi Iwan Nurhidayat and Rina Harimurti

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Exploring automatic assessment-based features for clustering of students' academic performance

Anita Qoiriah[1][0000-0002-7227-6642] , Yuni Yamasari[1][0000-0001-9719-3491], Asmunin[1], Andi Iwan Nurhidayat[1], Rina Harimurti[1]

[1]Informatics Department, Universitas Negeri Surabaya, Jln. Ketintang, Surabaya, Indonesia
{anitaqoiriah,yuniyamasari,asmunin, andyl34ks, 5rinaharimurti}@unesa.ac.id

Abstract. Many students have difficulty learning computer programming languages. Programming is a skill that requires a lot of practice, not just theory. Students are required to have the ability to all processes; analyze problems, design algorithms, translate algorithms into program code, and write program code with the correct syntax. The number of time students spend coding is the factor that has the highest impact on their programming skills. A basic programming lab work is implemented to increase students' programming skills with a lot of practice writing a code directly. Providing feedback on programming assignments is an integral part of a class on basic programming and requires substantial effort with personal teaching. It is needed an automatic assessment tool that can help the task of lecturers in evaluating assignments. Performance evaluation is one of the basics to monitor the progress of student performance. Grouping students according to their level of performance makes it easy for lecturers to monitor student performance levels and can provide learning according to the abilities of students in these groups. The clustering is used to group students based on the point of each lab work. The classification method used is K-Means Clustering. The cluster describes groups of students according to their performance. Based on the results of a case study with 31 students, it clusters students into 3 groups: 39% of people are in moderate ability, 45% of people have high abilities, and 16% of people are students whose programming abilities are still lacking system.

Keywords: K-Means, Clustering, Automatic assessment, Students' performance.

1 Introduction

Programming is a basic principle of computer science. Most importantly, practical knowledge of computer programming is a pre-requisite for higher-level computing courses[1], but programming is a course that for most students is considered rather hard. Many students have difficulty learning computer programming languages. Especially because of a lack of knowledge in the field of mathematics and informatics and does

not develop the ability to think abstractly and logically. Besides, there is also a lack of motivation and fear of programming because there are already difficult assumptions.

Most students learn programming languages by reading books or listening to lecturers' explanations. So it does not provide maximum results because programming is a skill that requires a lot of practice, not just theory.

The programming method begins by converting the issue into an algorithm and translating the algorithm into a program code. The hardest part is the application of algorithm specifications. The right algorithm will produce a program that is as expected. Consequently, students are required to have the ability to all processes; analyze problems, design algorithms, translate algorithms into a program code, and write a program code with the correct syntax.

Research [2] findings indicate that the number of time students spend coding is the aspect that has the largest effect on the results of the examination. Students' performance is associated with their programming experience and confidence in programming [3]. There is an interaction between practical learning and theory learning when students do programming tasks in the laboratory.

To help students and lecturers in the educational environment, the existence of educational tools is very important [4]. So are students understand the basic concepts of programming and develop problem-solving skills, programming basic courses are given learning programming through practical activities. A basic programming lab work is implemented to increase students' programming skills with a lot of practice writing a code directly. In this activity, students are given lab work modules which are consisted of lab work assignments and 1 last project. Each lab module has lab work assignments, both personal and group. Individual assignments worked live in class, and the results are directly demonstrated to the lecturer/assistant. Group assignments are worked on together. Finally, the students have to make lab work reports and collected them. The students do the last project at the last meeting with larger and more complex problem cases.

Lab work activities in the class are not enough time for students to practice some problem-solving skills in more complex programming. Because of that, many lab work assignments finally become homework for students. Furthermore, students will show it to the lecturer. The lecturer will give some tests and corrections on assignments given by students. Then students will improve and the results will be given back to the lecturer. This process requires a lot of time and energy from both the lecturer's side and the students' side. Feedback on programming assignments is an important part of an introductory programming class and involves significant effort on the part of the teacher [3]. Managing and assessing the results of the student's lab work assignments is very complex and time-consuming.

With the growth of internet technology and program analysis techniques, web-based tutoring systems can help the role of lecturers in teaching and training programming. Making automatic programming assessments can ease the task of instructors in evaluating students' lab work assignments so that lecturers have more time to concentrate on the material that will be given to students to improve their skills and follow the progress of student progress.

Based on the aforementioned problems, an application/tool is needed that can help ease the tasks of lecturers/assistants in evaluating assignments given to students as training materials to improve skills in programming and their ability to solve problems. This tool is expected to replace most of the tasks of lecturers/assistants without eliminating characterize of the lab work itself. Tools must be able to display assignments, live coding, upload program code, evaluate uploaded program code, compile, display compilation results, and grades. This tool has to display scores and rankings from all lab work participants who have uploaded the program code.

Performance evaluation is one of the basics to monitor the progress of student performance. Grouping students according to their level of performance makes it easy for lecturers to monitor student performance levels and can provide learning according to the abilities of students in these groups. Each group can have different treatment according to what is needed. Grouping can be done by clustering based on the similarity of the performance of each student. With this grouping, the assignment of practical work and monitoring student performance can be more targeted. In the traditional grouping, students are grouped based on their average scores. In this way, it is difficult to get a comprehensive view of the state of student performance.

In the educational domain, data mining techniques are very useful for improving current education standards and management. These techniques provide routes to various levels of ranking, determinations that provide new perceptions of how the masses can become experts in this education sector. Educational data mining (EDM), based on tasks, is divided into many categories, namely: classification [5][6][7] [8], clustering [9][10][11], association analysis[12][13][14] etc. Classification usually is applied for the prediction [15][16][17][18], for example, students' performance has long been an interesting area of research and it aids to distinguish the weak students or students at risk[19][2].

Data clustering is a method by which large data sets extract previously unknown, actual, positionally useful, and invisible patterns. The amount of data found in the education database continues to increase. The clustering technique is the most widely used technique for mapping [20][21][22]. The primary purpose of clustering is to classify students according to their capabilities and skill into homogeneous classes. This application can help instructors and students to improve the quality of education [23]. This study uses cluster analysis to segment students into groups according to their characteristics.

2 Material And Method

This application was built using Open-Source based technology including Ubuntu Linux, Laravel, Nginx, and MySQL. The process of compiling and evaluating a program code uses GCC and G ++ that is preinstalled on the operating system. The stages of application developers use the waterfall model approach.

The tools are arranged as shown in the flowchart in figure 1. Starting from the program code that has been sent by the student, the Memory Limit, Size Limit, Time Limit, and TotTimeLimit are determined. The next step is to check the Limit Exceeded and

Restricted Function, if it is correct then delete the temporary files and if it is wrong then set Outfile_File and stringCmd_Compile.

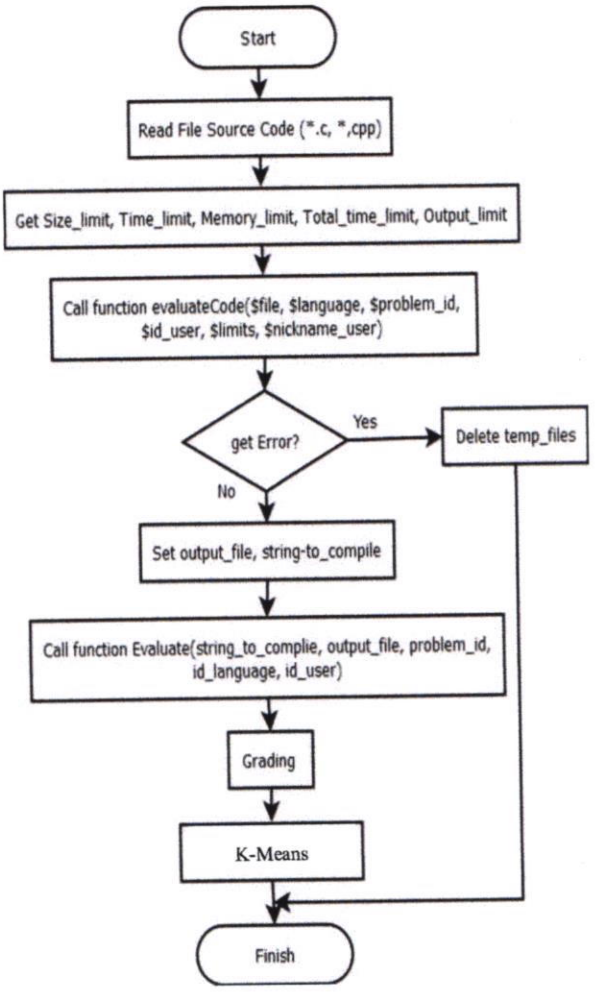

Fig. 1. Flowchart Automatic Assessment

The main modules in this application are evaluation, assessment, and clustering. The evaluation module will conduct an in depth evaluation of the program code sent, and be a determinant for the next process. The results of the process in the evaluation module are then processed in the assessment module. In the assessment module, a comparison process with the test case is carried out and a point calculation is performed. The clustering module is used to group students based on the point of each lab work. The clustering method used is K-Means Clustering.

2.1 Scoring

The assessment process is carried out by reading the input of test cases and comparing them with the output of test cases. The score lab works assignment is calculated as in equation (1) and (2).

$$\text{Score} = \text{weight of assignment x accuracy} \quad (1)$$

$$\text{Accuracy} = \text{total accepted / number of submit} \quad (2)$$

2.2 Data set Clustering

The data in this study were collected from 110 first semester students of the Department of Informatics. Students are participants in the Basic Programming course. The data collected is the result of an Automatic Programming Assessment Tools assessment from a basic programming lab work that uses C ++ Language. Data collection was carried out from the value of 3 lab work assignments that must be completed by each student.

2.3 K-Means Clustering

K-Means aims to minimize the Sum of Squared Error (SSE) between data objects with many k-centroids. K centroids in this study amounted to 3, they are a group into low, medium, and high programming abilities. The steps for the K-Means algorithm [8]:

1. From the data set to be clustered many k objects are chosen randomly as the initial centroid, cj.
2. Every object that is not centroid is inserted into the nearest cluster based on the Euclidean distance measure as in equation (3).

$$\text{Euclidean distance measure} = \| \text{xi (j)} - \text{cj} \|2 \quad (3)$$

3. Each centroid is updated based on the average of the objects in each cluster
4. Iterate for the second and third steps until all centroids are converging and stable, where all the centroids produced in the current iteration are the same as all the centroids produced previously.

Several distance measurements are used as a measure of similarity of data, one of which is the Euclid distance. The Sum of Squared Error (SSE) as in an equation (4).

$$j = \sum_{j=1}^{k} \sum_{i=1}^{n} \left\| x_i^{(j)} - c_j \right\|^2 \quad (4)$$

(4)

Where J is the objective function, k is the number of clusters that is 3, n is the number of data objects that is 41, *xi* is the value of the data object to *i*, *cj* is the centroid cluster *j*, $\| x_i^{(j)} - c_j \|^2$ is a distance function.

3 Result And Discussion

This study was carried out in the Department of Informatics Engineering, FT Unesa, for the lab programming of basic courses with 110 students. The programming language used is C ++. While doing a lab work assignment, every student must register for the application and doing the assignment provided. The score obtained by all of the students will be processed with the K-Means algorithm to classified students by their cluster.

3.1 Implementation

Before students start doing lab work assignments with automatic assessment applications, the lecture must create assignments first. Several things that must be included are the description of the assignments, the level of difficulty, the group of material assignments, points, or weight of the assignments, the output of the assignments. In addition to each assignment made, there are some time settings and program sizes.

To use this program, a student has to log in, it will proceed with working on the problems. The assignments that students work on can be chosen based on the problem group and the level of difficulty. Furthermore, students can work on the selected assignments like figure 2, directly write the program code on the application or use another editor.

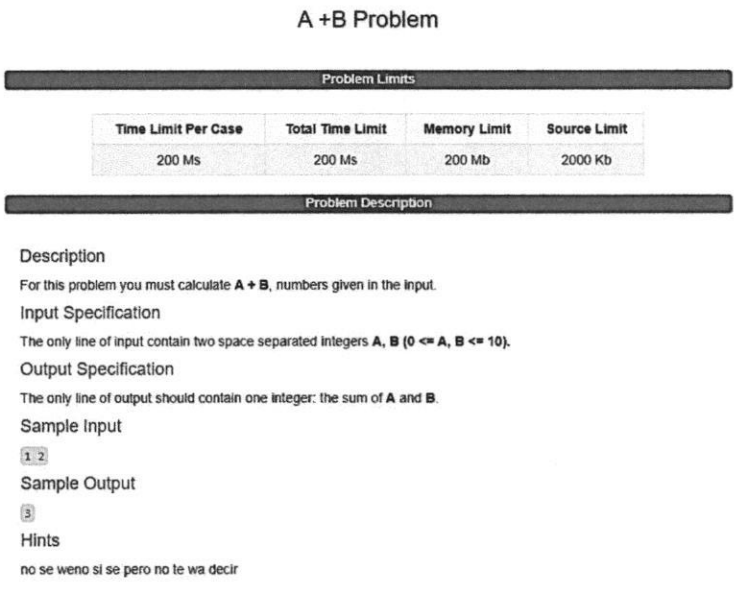

Fig. 2. Problems Description

The completed program is then uploaded to the application. and submitted. After the assignment has finished submitting, the execution results will come out, whether the program was received or there was still an error like in Figure 3. Code Testing is done by unit testing conducted during the development and acceptance testing, that is one by students.

An assessment of student work scores is calculated based on the percentage of accuracy multiplied by the weight of each question. Based on the results of a trial of 330 submitted answers, 124 answers have 100% accuracy, meaning that with 1 time the answer is correct. And 41 answers have accuracy below 50%.

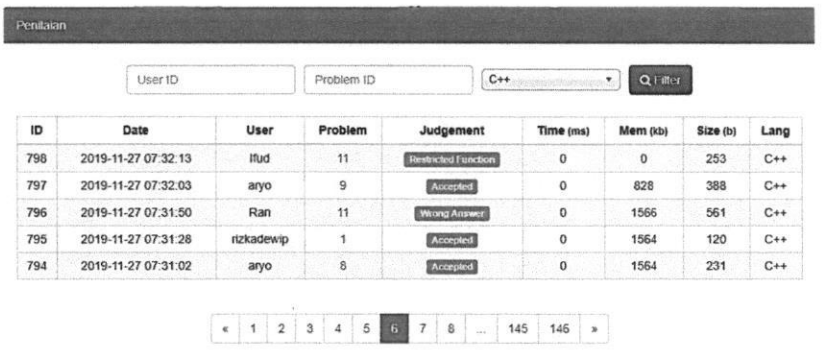

Fig. 3. List of programs subscribed

3.2 Clustering

The clustering feature of this tool is very important, especially for grouping students according to their abilities. So the lecturer can give learning according to the ability group of each student. In this way, it is hoped that maximum learning will be produced.

Raw data clustering is the scores of 3 lab work assignments generated by the Automatic programming assessment tool. So that the total data is 330 values. Furthermore, the data will be processed so that it becomes 3 clusters. The cluster describes groups of students according to their performance, groups that have weak, medium, and high abilities. Clustering with K-Means begins by determining the initial random centroid. By the number of groupings, each work lab assignment will be taken 3 initial centroids. The initial centroids are produced as in table 1

Table 1. Initial Centroid

Centroid 1			Centroid 2			Centroid 3		
81	65	65	65	81	65	65	65	81

Furthermore, from non-centroid data, the minimum distance from the initial centroid will be sought. The next process is to update the centroid value based on the average

value of the object minimum values. The same process applies to all subsequent data objects. The process is repeated until a stable centroid is produced, i.e. the centroid value now and then remains the same. A stable midpoint or centroid value will be generated as can be seen in Table 2.

Table 2. Centroid Data

Cluster	P1	P2	P3
Cluster 0	42	68.000	61.400
Cluster 1	50.357	51.071	80.500
Cluster 2	35.833	68.333	79.417

By using this centroid, the data will be grouped into 3 clusters. Clustering is determined based on the minimum distance between objects and centroids. The process will be repeated by determining the new centroid based on clustering results. The loop will stop until you get the same clustering result as before. Clustering results were obtained as shown in Figure 4, wherein cluster 3 there are 43 students with moderate ability, cluster 1 as many as 50 students with high ability, and cluster 0 as many as 17 students with programming ability still not enough.

The experimental result indicates that poor students of this subject are 16 %. Therefore, the teacher needs to improve the learning and teaching process to reduce the number of low students by a suitable instructional method. Furthermore, this system clustering of students is very useful because the system can support the teacher as a decision-maker to enhance better students' performance as soon as possible.

K-means

Proses Iterasi Selanjutnya

ID	Nama	P1	P2	P3	Centroid 1			Centroid 2			Centroid 3			C1	C2	C3
					70.00	57.50	71.75	35.56	74.44	72.67	40.00	53.53	80.29			
32	M. FAHRUR ROZI	30	50	80	41.524841962372			26.114289191935			10.608722826052			0	0	1
33	MAULIDA NURSANTI	20	80	60	56.074169632728			20.822009989432			38.888880158729			0	1	0
34	INTAN PRASTIKA	30	70	60	43.523700440105			14.531211236507			27.981154372184			0	1	0
35	KURNITA SARI	40	40	80	35.697513919039			35.490225414894			13.533107551483			0	0	1
36	LILING APRISTIANA	20	60	80	50.737683234456			22.457873897589			21.022467959326			0	0	1
37	IIS TIANAH	40	50	73	30.94854600785			24.842224135532			8.0996913521442			0	0	1
38	ARIFATUS SHOLEHA	50	40	73	26.604745817241			37.346165800521			18.3358937606			0	0	1
39	IKRIMATUS SHOLEHA	30	60	73	40.097537330864			15.476953834654			13.96441907134			0	0	1
40	DEFFA ERLIAN SARI	40	50	77	31.36578549949			25.214600928827			4.8254533465779			0	0	1
41	NAZILA QORIATUN NISA	40	50	80	32.004882440028			25.898959438557			3.541892149685			0	0	1
42	DEWI LUTFIANA	30	60	80	40.918363848033			17.121801891156			11.914057315573			0	0	1
43	TIWI ROBIANINGSIH	40	50	83	32.90611645272			26.902343764066			4.4502808900113			0	0	1
44	AMALIYAH	30	60	83	41.627064513367			18.604733268714			12.214949656631			0	0	1
45	RULLI BAGUS PRATAMA	40	50	83	32.90611645272			26.902343764066			4.4502808900113			0	0	1

Fig. 4. Clustering results

4 Conclusions

The automatic assessment tool makes it easy for the user evaluation of lab work assignments. From the student side, the ease is inside testing and collection of program code, while from the lecturer side also makes it easy to manage questions and answers and get student grades automatically. Questions are made with several settings, namely the time, file size, and the weight of each question. Assessment questions are the product of the process of the results received multiplied by the weight of the questions.

To make it easier for lecturers to provide appropriate learning, the grouping is carried out in class according to students' abilities. Grouping using the K-Means method. Based on the results of trials with 110 students, The results of clustering can classify students into 3 groups: 39% of people are in moderate ability groups, 45% of people are students with high abilities, and 16% of people are students whose programming abilities are still lacking.

The system can give the early warning for the teacher to solve relating to low students' performance in a specific subject compared to the conventional system

References

1. Ayalew, Y., Tshukudu, E., and Lefoane, M.: Factors Affecting Programming Performance of First-Year Students at a University in Botswana. African J. Res. Math. Sci. Technol. Educ. 22(3), 363–373 (2018).
2. Satratzemi, M., Xinogalos, S., Tsompanoudi, D., and Karamitopoulos, L.: Examining Student Performance and Attitudes on Distributed Pair Programming. Sci. Program. 2018. (2018).
3. Thuné, M., and Eckerdal, A.: Analysis of Students' learning of computer programming in a computer laboratory context. Eur. J. Eng. Educ. 44(5), 769–786 (2019).
4. Kautsar, I.A., and Sarno, R., A supportive tool for project-based learning and laboratory-based education. Int. J. Adv. Sci. Eng. Inf. Technol. 9(2), pp. 630–639 (2019).
5. Yamasari, Y., Mardi, S., Nugroho, S., Yoshimoto, K., Takahashi, H., and Purnomo, M.H.: Information and Control ICIC International. Int. J. Innov. Comput. 15(6), 2085–2107 (2019).
6. Shanmugarajeshwari, V., and Lawrance, R.: Analysis of students' performance evaluation using classification techniques. In: 2016 International Conference on Computing Technologies and Intelligent Data Engineering (ICCTIDE'16), pp. 1–7. IEEE, Kovilpatti, India (2016).
7. Yahya, A. A.: Swarm intelligence-based approach for educational data classification. J. King Saud Univ. – Comput. Inf. Sci. 31(1), 35-51 (2019).
8. Mhetre, V., and Nagar, M.: Classification based data mining algorithms to predict slow, average, and fast learners in an educational system using WEKA. In: 2017 International Conference on Computing Methodologies and Communication (ICCMC), pp. 475–479. IEEE, Erode, India (2017)
9. Wang, S., Hu, Y., Liu, Y., Guo, Z., and Shou, G.: Student clustering and learning atmosphere analysis based on trajectory data. In: 2017 12th International Conference on Computer Science and Education (ICCSE), pp. 208–213. IEEE, Houston, TX, USA (2017)

10. Park, Y., Yu, J. H., and Jo, I.-H.: Clustering blended learning courses by online behavior data: A case study in a Korean higher education institute. Internet High. Educ. 29, 1–11 (2016).
11. Yamasari, Y., Nugroho, S. M. S., Harimurti, R., and Purnomo, M. H.: Improving the cluster validity on student's psychomotor domain using feature selection. In: 2018 International Conference on Information and Communications Technology (ICOIACT), pp. 460–465. IEEE, Yogyakarta, Indonesia (2018).
12. Yang, G., Mabu, S., Shimada, K., and Hirasawa, K.:A novel evolutionary method to search interesting association rules by keywords. Expert Syst. Appl. 38(10), 13378–13385 (2011).
13. Abdullah, Z., Herawan, T., Ahmad, N., and Mat Deris, M.: Extracting highly positive association rules from students' enrollment data. Procedia - Soc. Behav. Sci. 28, 107–111 (2011).
14. García, E., Romero, C., Ventura, S., and De Castro, C.: A collaborative educational association rule mining tool. Internet High. Educ. 14(2), 77–88 (2011).
15. Pradeep, A., Das, S., and Kizhekkethottam, J. J.: Students dropout factor prediction using EDM techniques. In: 2015 Proceedings of the IEEE International Conference on Soft-Computing and Network Security(ICSNS). IEEE, Coimbatore, India (2015).
16. Altujjar, Y., Altamimi, W., Al-Turaiki, I., and Al-Razgan, M.: Predicting Critical Courses Affecting Students Performance: A Case Study. Procedia Comput. Sci. 82, 65–71 (2016).
17. Harimurti, R., Yamasari, Y., Ekohariadi, Munoto, and Asto, B. I. G. P.: Predicting student's psychomotor domain on the vocational senior high school using linear regression. In: 2018 International Conference on Information and Communications Technology (ICOIACT), pp. 448–453. IEEE, Yogyakarta, Indonesia (2018)
18. Shahiri, A. M., Husain, W., and Rashid, N. A.: A Review on Predicting Student's Performance Using Data Mining Techniques. Procedia Comput. Sci. 72, 414–422 (2015).
19. Gulwani, S., Radiček, I., and Zuleger, F.: Automated clustering and program repair for introductory programming assignments. In: Proceedings of the ACM SIGPLAN Conference on Programming Language Design and Implementation (PLDI), pp. 465–480. ACM, Philadelphia, USA (2018)
20. Harwati, H., Alfiani, A. P., and Ayu Wulandari, F.: Mapping Student's Performance Based on Data Mining Approach (A Case Study). Procedia - Social and Behavioral Sciences. 38(1), 173–177 (2015).
21. Pang, Y., Xiao, F., Wang, H., and Xue, X.: A Clustering-Based Grouping Model for Enhancing Collaborative Learning. In: 13th International Conference on Machine Learning and Applications, pp. 562–567. IEEE, Detroit, USA (2014)
22. Huang, L.: Teaching Management Data Clustering Analysis and Implementation on Ideological and Political Education of College Students. In: 2016 International Conference on Smart Grid and Electrical Automation (ICSGEA), pp. 308–311. IEEE, Zhangjiajie, China (2016)
23. Shashikant, M., and Borgavakar, P.: Evaluating Student's Performance using K-Means Clustering. International Journal of Engineering Research & Technology (IJERT) 6(5), 114-116 (2017).