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Real-time Monitoring System of Students' Understanding Level with Tablets

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The aim of this study is to grasp students' understanding level during a class so that teachers can explain again the points that the students do not understand well. For that purpose, we have developed a system which can monitor students' learning state using a quiz test. The system can monitor students' answers in real-time by using two-way communication method, which is difficult with the quiz test programs in other e-learning systems. The system is consisted of two components: e-learning subsystem and real-time monitoring subsystem. We also utilize tablets for this system. In order to develop this system, we adopted technology such as Node.js, NoSQL database, WebSocket, Single Page Application, and so on. In this paper, we propose a new teaching method named "Test-Driven Education". The method is based on "Test-Driven Development" in software development. To perform the method, teachers need repetition of quiz tests in their classes. Our system is expected suitable for this purpose.

Keywords: tablet; two-way communication; real-time; Test-Driven education

I. INTRODUCTION

Recently, tablets have been introduced to places of education, and for that purpose many application programs for tablets have been developed (Crompton & Burke, 2018; Major *et al.*, 2017; Algoufi, 2016). We also developed game-based educational application software using tablet's multi-touch function effectively (Yamashita et al., 2012). On the other hand, as Nagatomo (2016) discussed, it is also pointed out that even if students are temporarily interested in such new devices at the beginning of the introduction, some students can be easily get tired. In addition, despite the progress of digitization of books, some of the e-textbooks are just digitization of paper books, and do not fully utilize tablet's advanced functions such as communication functions. Although such e-textbooks have a certain degree of educational effect (Joo *et al.*, 2017; Weng *et al.*, 2018), we hope more effective use of tablets for education.

Currently, popular e-learning systems have many functions such as a quiz test, teaching materials management, grades management, etc. (Nash & Rice, 2018), and students can learn using these systems during classes and in their homes. Although, by using existing e-learning systems, teachers can refer to the results of the quiz test and check the understanding level of the students, but usually it is not in the classes to refer to them. Furthermore, in the case of a paper quiz test, as teachers take much time to mark the quiz test, it will be in next classes that teachers explain misunderstanding points to students again.

The purpose of this study is to develop a system which enable teachers grasp the understanding state of students and explain again the misunderstanding points immediately in the classes. In this study, we have developed the prototype of the system which can monitor students' learning state in real-time by utilizing tablets and two-way communication methods.

There are already a lot of studies on computer-based testing system, and e-testing (also known as e-assessment) has become a common feature of e-learning systems (Ueno, 2005; Ueno, 2009; Thelwall, 2000; Chua, 2012; Deutsch *et al.*, 2012). Additionally, Recent e-testing systems have introduced Computer-adaptive Testing method (Linden &

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Xiong, 2013) based of item response theory, which enables reducing the testing time while keeping the reliability of test score. However, many of those previous studies are aimed at grading student ability accurately and efficiently, and few were aimed at supporting teachers in class.

In terms of real-time student's monitoring, as the importance of knowing students' emotions in class is recognized, many studies to estimate students' emotional states have been conducted. To obtain students' mental states in real-time, various kinds of information such as eye movement (Muldner *et al*., 2019), facial expression (Sarrafzadeh *et al*., 2003; Deshmukh *et al*., 2018; Deniz *et.al*., 2019), physiological information (Tawatsuji *et al*., 2018), mouse movement and keystroke (Salmeron-Majadas *et al*., 2014; Nassr *et al*., 2019) have been focused on. On the other hand, our system measures students' understanding level using quiz test in real-time.

II. MATERIALS AND METHOD

A. System Architecture

As shown in Figure 1, our system consists of an e-learning subsystem and a real-time monitoring subsystem (hereinafter, referred to as a monitoring subsystem). The e-learning subsystem provide several functions such as user management, result data management, content management and quiz test management. The implementation method of the e-learning subsystem part is similar to general e-learning systems. On the other hand, the real-time monitoring subsystem, which is a characteristic point of this study, has a configuration different from that of conventional web applications in that it uses WebSocket protocol (Fette & Melnikov, 2011) for two-way communication and places NoSQL type of high-speed database at the back-end of the server.

Each subsystem is configured as a server program, that is web server and WebSocket server, respectively. We have been developing these two subsystems on Linux using Node.js (https://nodejs.org) which is run-time environment to execute JavaScript programs. As Node.js adopts single-thread process model and non-blocking I/O calls (Brown, 2014), we can expect quick processing and response from the servers.

In our system, we adopted two NoSQL type databases, MongoDB (https://www.mongodb.com) and RedisDB (https://redis.io). MongoDB is called "document-oriented" database among NoSQL type databases, and it is good at processing hierarchically structured data and processing data in JSON (JavaScript Object Notation) format. The advantage of using JSON format is that as it is the same as the object representation format of JavaScript language, no format translation between raw data and data objects in JavaScript programs is needed. In our system, MongoDB is used to store quizzes written by teachers.

RedisDB, which is also a kind of NoSQL database, is a key-value-store type database. It is not suitable for storing data with complicated structure, but can be accessed very fast instead. In our system, we adopted this high-speed database as we needed to store the answer to each quiz as soon as a student answered a quiz so that teachers could monitor the state of answers of students in real-time.

B. Usage of the System and Data Flow

In this section, we describe how to use our system and data flow during the use of the system.

At first, students and a teacher must login to the e-learning subsystem from a web browser on their tablets with ID and password. As the e-learning subsystem, which is a simple web server, is constructed by popular web application technology as well as many other existing e-learning systems, HTTP (HyperText Transfer Protocol) is used for communication between the client and the server.

When students click a link to a quiz test page on the e-learning subsystem, transition to the quiz test page occurs, changing protocol from HTTP to WebSocket, the web browser on the client tablet switches the destination of connection from the e-learning subsystem to the monitoring subsystem. Once the destination has changed, students' answers of quizzes continues to be sent to the server on the monitoring subsystem, followed by sending the received data to both the RedisDB for saving and teacher's tablet for monitoring.

On receiving the data, namely students' answers, a teacher can watch them in the web browser on the teacher's tablet by

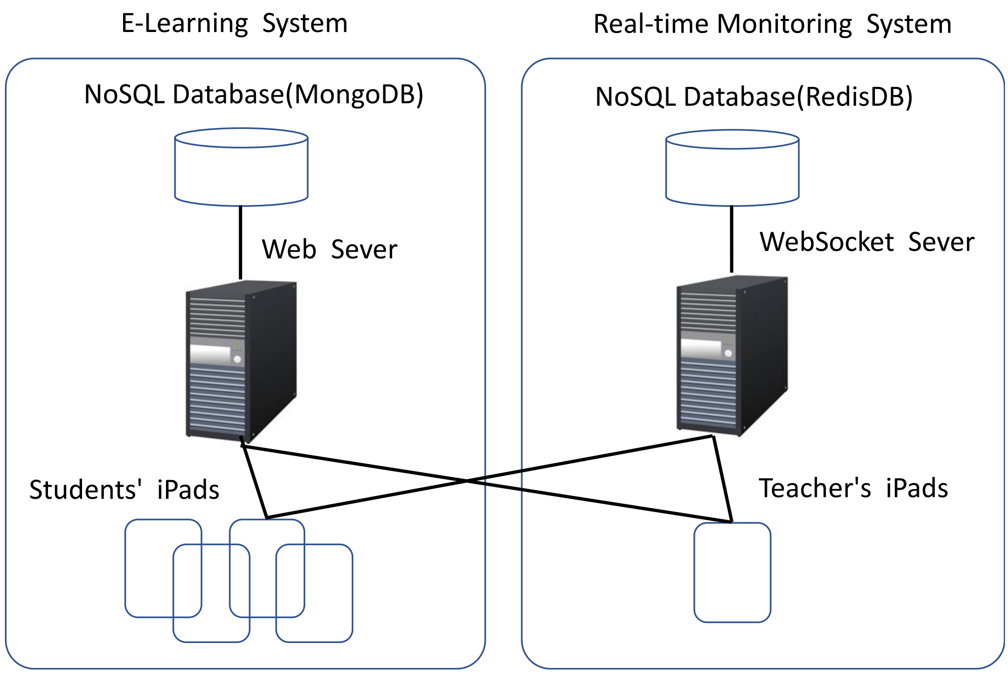

Figure 1. System Architecture

computer graphics converted from raw-data. In this study, we use D3.js (https://d3js.org) graphics library for this purpose.

C. Role of high-speed Database

We have already briefly mentioned key-value store type database RedisDB in the previous section. In this section, we explain the role of the database in detail.

As mentioned above, in our system, each time a student answer a quiz, the information is stored into the RedisDB through the monitoring server. There are three reasons for us to store data to the database as follows:

- reloading students' answers
- recovering from trouble
- getting details of students' quiz test state

The first reason is that as students' and teacher's tablets are always connected and data from students' tablet is sent to teacher's tablet one after another using WebSocket protocol during a quiz test, if the teacher refers to other pages on the tablet or looks aside during the quiz, the data is lost. Therefore, in parallel with sending students' answers to teacher's tablet, we save the data to high-speed database RedisDB, which stores data in key-value-store structure onto memory, namely not onto disk storage; hence high-speed access is possible. As a result, even if the data is lost for some reason, the teacher can acquire all the data from RedisDB again, so that the monitoring can be continued.

The second reason is for restoration at the time of some trouble on tablets, network, servers, and so on. When some trouble occurred during a quiz test, it is desirable to restore lost data as soon as possible and go back to the state just before the occurrence of the trouble. However, in the case of a quiz test supported in general e-learning systems, each student's answer is sent to the e-learning server, which is usually a web server, after finishing answering all the questions and pressing a "submit" or "send" button. Therefore, all answers of students may be lost if some troubles occurs like crashing of tablets before saving the data. On the other hand, in our system, students' answers are immediately and automatically saved to the database every time they answer one quiz, so that all the data can be recovered.

The third reason is to obtain details of the answers of the students during a quiz test. As mentioned above, in a general e-learning system, students' answers are sent to the server all together after completion the answer, so that the teacher cannot know the state of students' answer to each question. Whereas, in our system, every time a student answers one question, the answer is sent to the server and stored in real-time, so teachers can get the details such as which question

Figure 2. Quiz screenshot

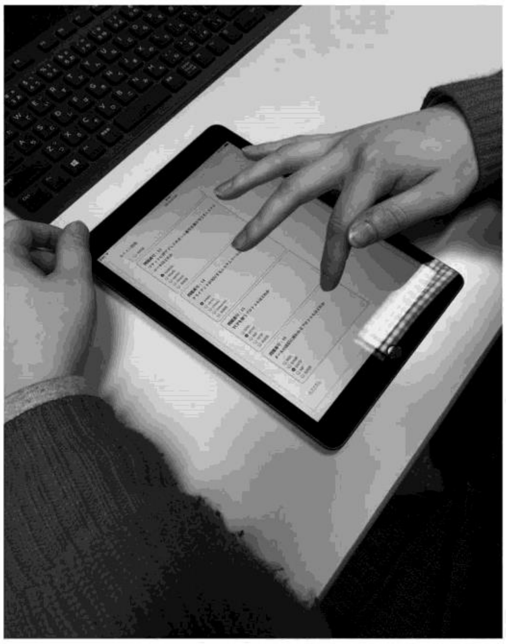

Figure 3. Answering student

students are taking time to, that means the question is difficult, and which question they has finished answering.

D. Two-way Communication with WebSocket

For the communication between student's and teacher's tablets, we adopted WebSocket protocol instead of HTTP which is commonly used for web application development. That is because a http server can only respond to requests from clients, and cannot push data from the server to the client (Fette & Melnikov, 2011). Therefore, if we used HTTP on the monitoring subsystem, the server cannot send the data received from students' tablets to the teacher's tablets. In the case of WebSocket, on the other hand, once the connection is established and as long as maintained, it is possible to send and receive freely between the client and the server.

In our system, SPA(Single Page Application) method is also adopted to avoid disconnection of WebSocket due to page transition.

III. RESULT AND DISCUSSION

For evaluation of our system, we have tested it in the author's class named "Network Programming". This section describes the result of our test.

Quizzes are prepared in advance on the server. Students select one of those quizzes according to the instruction of the teacher, then the quiz is loaded into the browser on a tablet.

Figure 2 and 3 show the screenshots of the quizzes and how a student is answering quizzes on the tablet, respectively. In the current system, each quiz is four-choice formula that can be answered by touch operation, and written in Japanese. As shown in Figure 3, there is no "send" button on the quiz page because the moment a student choose one of the four choices, the answer is sent to the server automatically.

Figure 4 shows the screenshot of teacher's tablet, in which a part of the screen is magnified. In this paper, the image is shown in grayscale, but in the real screen, it is colored: "correct" and "wrong" are green and red, respectively. The numbers from 1 to 4 are answers chosen by students among the four-choice. Number 0 means the quiz is not answered yet. The mosaiced numbers are student IDs. Numbers from 1 to 12 aligned at the top of the magnified image are quiz numbers. In this test, we could confirm that the chosen numbers and its background colors changed immediately as soon as students answered.

By using this system, we could know the points students didn't understand well and we could explain again during the same class, which was difficult so far.

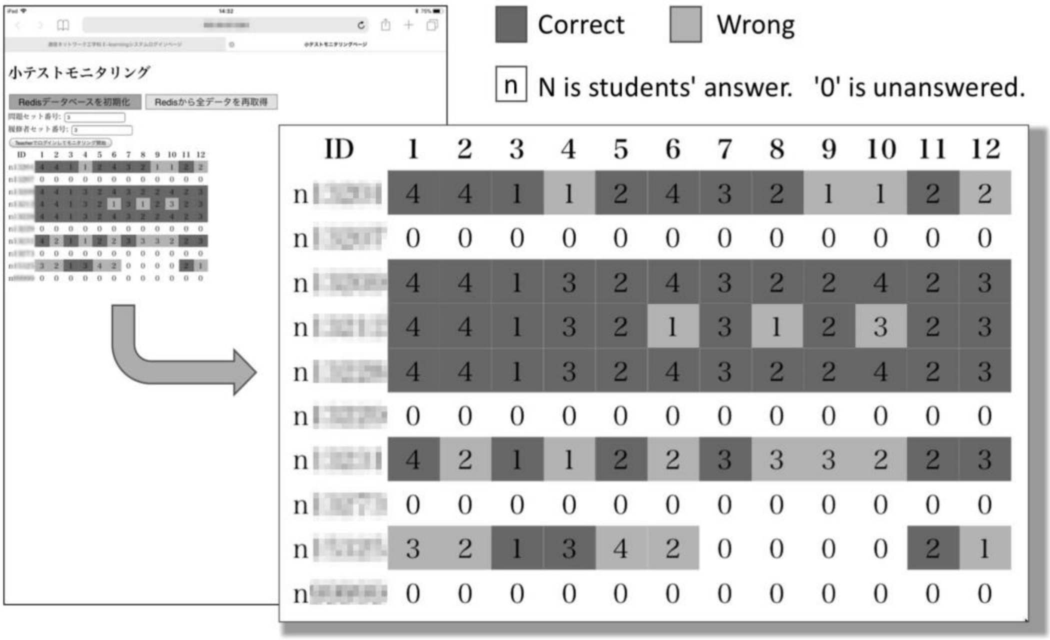

Figure 4. Monitoring page for the teacher

IV. CONCLUSION

We have developed a prototype of a e-learning system with a function of real-time monitoring of students' understanding level during a class. We actually used this system in our class for evaluations of the effectiveness of it.

As a result, we could know which part of the class students understood well and which part is unknown by using this system. Furthermore, we could obtain detailed information on the progress of students' quiz test and which quiz students were taking time to solve. This enabled me to grasp the student's situation and explain the misunderstanding point again during the class. Since the present system is still a prototype, there are only four-choice formula type of quizzes, however, as more complex quizzes are added, obtaining such detail information will be more useful for analyzing students' comprehension. From the above reasons, we confirmed that it was valuable or worthwhile for education. In addition, we suppose the feature is more effective for the education such as a remote lecture.

In this paper, we also reported the configuration of the system in detail, especially the two-way communication using WebSocket protocol, role of the high-speed database, single page application, and so on. Besides, as this study was originally started with the aim of utilizing tablets, we used tablets in the demonstration experiment. But as this system is composed using standard web technology, it can be run on other computers such as a smartphone and a PC.

As a future work, we propose a new teaching method using the system reported in this paper.

At first, we discuss the similarities between software development and a class.

Table 1 shows the similarity between software development process and a class. In the development of software, we first clarify the requirements for the system and determine the specifications of the system. After defining specifications, we perform the design and the programming according to the specifications. At the last step of the processes, we check

Table 1. Comparison of software development process and class

Software Development	Traditional Class
definition of requirement	determination of class contents
design	planning a class
programming	giving a class
test	examination (quiz)

through the test process whether the system is made according to the specifications and the design. On the other hand, there are steps similar to software development in implementation of a class by teachers. Teachers decide the scope and contents of a class at the beginning of certain period such as a school year, semester, and even also the class. Following this, they plan the detail of classes and give a class according to the plan. Then after classes in certain term, they perform an examination for checking and grading students' understanding level. Note that both test in software development and examination in classes are for checking the achievement level; test is for checking the degree of conformance of the system to requirements and specifications, and examination is for checking the level of students' understanding of the classes, in addition, the test and the examination are performed at end of each process.

For a long time, the Waterfall model (Bell & Thayer, 1976) has been adopted for software development, but in recent years Test-Driven Development (TDD) method is also used for the purpose of improving productivity and flexibility. In TDD, developers begin with writing a test code (Beck, 2003), which is different from Waterfall model. Then they write the code of the software, and check if the code passes the given test. The first code is not necessary perfect at this stage, as code modification, which is called "refactoring" and testing are repeated in TDD. The code gradually become more sophisticated and of better quality by this repetition.

We propose an application of TDD to education due to the similarity mentioned above. To do that, teachers need to prepare quizzes before classes; the quizzes can be easy at the initial stage. Note that, those quizzes are not for grading but for monitoring. Then, while repeating the examination and a lecture in a class, they can gradually teach more advanced contents and give more difficult quizzes according to the students' understanding level. In order to implement this method, it is necessary to know the understanding state of students in detail. Our system is available for this purpose. That is because teachers can grasp the detailed state in real-time by using the system.

Khanam & Ahsan (2017) analyzed the advantages and disadvantaged of TDD in terms of quality, learning curves, productivity, etc. and showed the conditions where TDD is effective for software development. We want to investigate the effectiveness of applying TDD to education.

V. ACKNOWLEDGEMENTS

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VI. REFERENCES

Algoufi, R 2016, ‘Using Tablet on Education’, *World Journal of Education*, vol. 6, no. 3, pp. 113-119.

Beck, K 2003, *Test-driven development by example*, Addison-Wesley, Boston.

Bell, TE & Thayer, TA 1976, ‘Software requirements: Are they really a problem?’, *Proceeding of ICSE '76 Proceedings of the 2nd international conference on Software engineering*, pp. 61-68.

Brown, E 2014, *Web Development with Node and Express*, O’Reilly Media, Gravenstein Highway North Sebastopol, CA.

Chua, YP 2012, ‘Effects of computer-based testing on test performance and testing motivation’, *Computers in Human Behavior*, vol. 28(5), pp. 1580-1586.

Crompton, H & Burke, D 2018, ‘The use of mobile learning in higher education: A systematic review’, *Computers & Education*, vol. 123, pp. 53-64.

Deniz, S, Lee, Dakyung, Kurian, G, Altamirano, L, Yee, D, Ferra, M, Hament, B, Zhan, J, Gewali, L & Oh, P 2019, ‘Computer Vision for Attendance and Emotion Analysis in School Settings’, *2019 IEEE 9th Annual Computing and Communication Workshop and Conference (CCWC)*, pp. 134-139.

Deshmukh, SP, Patwardhan, MS & Mahajan, AR 2018, ‘Feedback based real time facial and head gesture recognition for e-learning system’, *CoDS-COMAD '18 Proceedings of the ACM India Joint International*

Conference on Data Science and Management of Data, pp. 360-363.

Deutsch, T, Herrmann, K, Frese, T & Sandholzer, H 2012, ‘Implementing computer-based assessment - A web-based mock examination changes attitudes’, *Computers & Education*, vol. 58(4), pp. 1068-1075.

Fette, I & Melnikov, A 2011, The WebSocket Protocol, RFC 6455, viewed 6 July 2019, <https://tools.ietf.org/html/rfc6455>.

Joo, YJ, Park, S & Shin, EK 2017, ‘Students' expectation, satisfaction, and continuance intention to use digital textbooks’, *Computers in Human Behavior*, vol. 69, pp. 83-90.

Khanam, Z & Ahsan, MN 2017, ‘Evaluating the Effectiveness of Test Driven Development: Advantages and Pitfalls’, *International Journal of Applied Engineering Research*, vol. 12, no. 18, pp. 7705-7716.

Linden, WJ & Xiong, X 2013, ‘Speededness and Adaptive Testing’, *Journal of Educational and Behavioral Statistics*, vol. 38(4), pp. 418-438.

Major, L, Haßler, B & Hennessy, S 2017, ‘Tablet Use in Schools: Impact, Affordances and Considerations’, eds Marcus-Quinn, A & Hourigan, T, in *Handbook on Digital Learning for K-12 Schools*. Springer, Cham, pp.115-128.

Muldner, K, Christopherson, R, Atkinson, R & Burleson, W 2019, ‘Investigating the Utility of Eye-Tracking Information on Affect and Reasoning for User Modeling’, eds Houben, GJ, *et al.*, in *User Modeling, Adaptation, and Personalization. UMAP 2009. Lecture Notes in Computer Science*, Springer, Berlin, Heidelberg, vol. 5535, pp. 138-149.

Nagatomo, Y 2016, ‘A Study on the Current State of Lessons Using ICT’, *Bulletin of the Integrated Center for Educational Research and Training*, Yamaguchi University, No. 42, pp. 21-30. (in Japanese)

Nash, SS & Rice, W 2018, *Moodle 3 E-Learning Course Development*, 4th edn, Packt Publishing, Birmingham, UK.

Nassr, RM, Saleh, AH, Dao, H & Saadat, MN 2019, ‘Emotion-Aware Educational System: The Lecturers and Students Perspectives in Malaysia’, eds Lee, S *et al.*, in *Proceedings of the 13th International Conference on Ubiquitous Information Management and Communication (IMCOM) 2019, Advances in Intelligent Systems and Computing*, Springer, Cham, vol. 935, pp. 618-628.

Salmeron-Majadas, S, Santos, OC & Boticario, JG 2014, ‘An evaluation of mouse and keyboard interaction indicators towards non-intrusive and low cost affective modeling in an educational context’, *Procedia Computer Science*, vol. 35, pp. 691-700.

Sarrafzadeh, A, Hosseini, HG, Fan, C & Overmyer, SP 2003, ‘Facial expression analysis for estimating learner's emotional state in intelligent tutoring systems’, *Proceedings 3rd IEEE International Conference on Advanced Technologies*, pp. 336-337.

Tawatsuji, Y, Uno, T, Fang, S & Matsui, T 2018, ‘Real-time estimation of learners’ mental states from learners’ physiological information using deep learning’, eds Yang, JC *et al.*, in *Proceedings of the 26th International Conference on Computers in Education*, pp. 107–109.

Ueno, M 2005, ‘Web based Computerized Testing System for Distance Education’, *Educational technology research*, vol. 28, no. 1, pp. 59-69.

Ueno, M 2009, ‘e-Testing : Advanced Testing Technology’, *The journal of the Institute of Electronics, Information and Communication Engineers*, vol. 92, no. 12, pp. 1017-1021.

Thelwall, M 2000, ‘Computer-based assessment: a versatile educational tool’, *Computers & Education*, vol. 34(1), pp. 37-49.

Weng, C, Otanga, S, Weng, A & Cox, J 2018, ‘Effects of interactivity in E-textbooks on 7th graders science learning and cognitive load’, *Computers & Education*, vol. 120, pp. 172-184.

Yamashita, Y, Mori, K, Takajo, H & Johnston, R 2012, ‘The Development of Support System Using IPAD for Learning English’, *Proceedings of ISATE 2012, International Symposium on Advances in Technology Education*.