Development and Evaluation of a Large-Scale Agent-Based System for Information Literacy Education – Improving the Automatic Collection of Learning Results through Template Matching

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Abstract

Freeware learn-to-touch-type software, which is available for download without charge, caters for individual learning style but, in many cases, is not equipped with the features to manage the entire learning of the students. Using this type of training software for individual learning styles, our research developed a learning management system for the automatic collection of learning results in a large-scale training session. This system uses template matching to convert the image data on the achievement results screen into text data, and stores the results in a database. Our system was applied in teaching 640 students, and learning was shown clearly to be effective by including a comparison with another faculty (764 students) that did not use the system. In addition, an improvement to the image processing for the automatic collection of learning results was developed.

Key Words: distributed agent process, information literacy education, large-scale practice system, managing learning, template matching

1. Background and objective

The Faculty of Economics at Kinki University carried out a major overhaul of the information literacy curriculum from 2008. As a result of "information" subject being made compulsory in high schools, information literacy became a standard requirement for the university, and the curriculum was changed to support the acquisition of the qualification. The number of students enrolled for these subjects allocated over one or two years is around 700, which is almost all of the enrolled students. For a total of six subjects the enrollments are over 4700 and the demand for information literacy education is high.

Even for a big faculty such as this one, it is necessary to set a uniform educational level for information literacy. A standardized text was used for subjects targeting the MOS exams, and the simulated problems of the companion CD-ROM were used as standardized exercises. These simulated problems were for individual learning styles but, as the paper-based results needed to be collated manually, considerable cost was incurred in this information collection because of the large numbers of students. In order to resolve this, as already reported [1] [2] [3], a system was developed to automatically collect the learning implementation results using electronic texts available in the market, and it became possible to understand the progress of each person as well as for teaching staff to manage teaching. In addition, this system was applied to lesson exercises and clearly contributed to the effectiveness of learning.

In the system developed in the previous research, the score results screen (image data) of simulated problems was converted to text data through template matching [4], and the results were transferred to a database to manage the learning. As the developed system was an external application, the simulated problem of regular electronic text was monitored, and the timing for capturing the score results screen was discretionarily chosen. In the previous system, the score results screen was successfully acquired at the time of PowerPoint completion, but a similar mechanism may not be applicable in all cases.

For the application described in this report, the achievement results screen vanishes at the time the application ends, so it is not possible to capture the achievement results screen using the previous method. In order to solve this problem, the system used in this report monitors the regular application screen. When a portion of the screen changes, the screen image is captured, thus successfully acquiring the achievement results screen.

The system described in this report aims to improve the speed of touch-typing, and has been adopted for the information literacy course. After automatically acquiring the achievement results screen (image data) of a freeware typing practice software, the achievement results screen data are converted to text data through template matching. The converted text data are sent to the SQL database. This

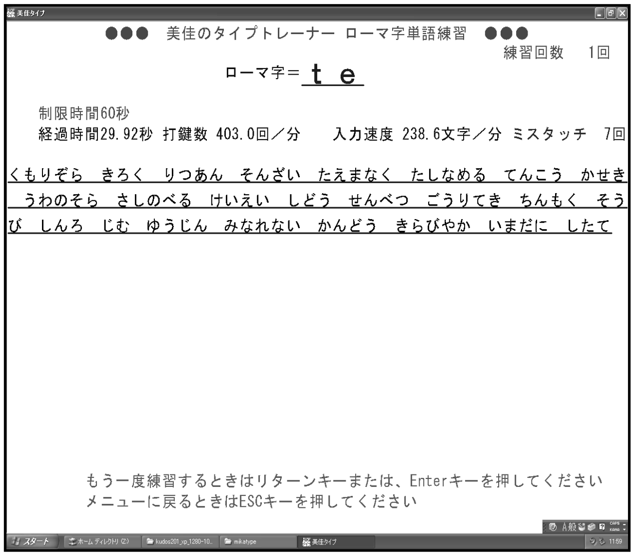

Fig. 1 Mikatype achievement results screen

completes the learning results automatic collection system (hereinafter, this system) that allows the monitoring of each person's progress, as well as the management of teaching by the teaching staff, to be done through the Web. Furthermore, testing with 640 students clearly showed learning was effective. Additionally, a comparison of achievements was also attempted with another faculty that was not using this system. Although it was not being used in tutorials, studies were also made to improve the image processing method for the automatic collection of learning results at reduced development cost.

2. Proposed method and developed system

2.1 Typing software used in learning

The typing training software used in this research is a freeware package, "Mika's Type Trainer Ver. 2.06"[5] (hereinafter, Mikatype) for Microsoft Windows. This software was developed for practicing touch-typing, and it is used at many educational locations. The software caters for individual learning styles and does not have a mechanism for collecting assessment results. Although it has multiple practice modes, the current system collects the achievement of the "roman-character word practice" mode, which measures how many Hiragana characters can be entered in one minute.

In this system, in order to collect the data for "practice count," "elapsed time," "keystroke count," "input speed," and "keystroke errors" shown in Fig. 1, a mechanism is constructed to capture the image of the achievement results screen, convert the image data to text data through template matching, and store them.

2.2 Fixed-coordinate template matching

In order to construct the learning management system, recognition is carried out for each item displayed on the achievement results screen and converted to text data. The achievement results screen for the typing is captured as bitmap image data. In order to convert this image data to achievement text data, a matching process is carried out by registering the application logo and numerical glyphs used by the application as a template, and superimposing this over the captured image. In template matching, the template image T is superimposed over the brightness value F of each pair of coordinates (i, j) on the target image, and judgment is made on whether items similar to the template remain in the target image. The metric of squared brightness is used in order to judge similarity. In the case of an $m \times n$ image and an $x \times y$ template, the residual R is given by Formula (1).

$$R(i,j) = \sum_{\Delta x, \Delta y}^{x, y} \{F(i+\Delta x, j+\Delta y) - T(\Delta x, \Delta y)\}^2 \quad (1)$$
$$\rightarrow \min(\forall (i,j) \in m \times n)$$

Template matching generally looks for the position of minimum residual R and, although it is possible to seek out the coordinates of F in the matching target image, this system used the method of measuring the positions of the logo and numbers in advance for each resolution and executed the matching process for the respective positions. For example, when capturing the seconds (ten-digit number) of elapsed time for Mikatype using SXGA (1280×1024) resolution, the adopted method was to search the 13×23 template images representing the digits 0 to 9 from the point of X coordinate 195 and Y coordinate 223, and replace the numerical text with the image where residual is 0. This system was developed to be capable of working at XGA and SXGA resolutions.

2.3 Overview of developed system

Fig. 2 shows the developed system's structure and process flow. A distributed agent, running on the client and using the above method, converts the Mikatype achievement results screen (image data) to text data through template matching, and the achievement result is transferred to the web server. After downloading the agent program from the file server common to the practice PCs, it executes in parallel with Mikatype. While Mikatype is executing, the agent also monitors image changes in the background. The web server function consists of collecting data from the distributed agent, managing the database, and generating HTML to display the student's progress using Active Server Pages (ASP).

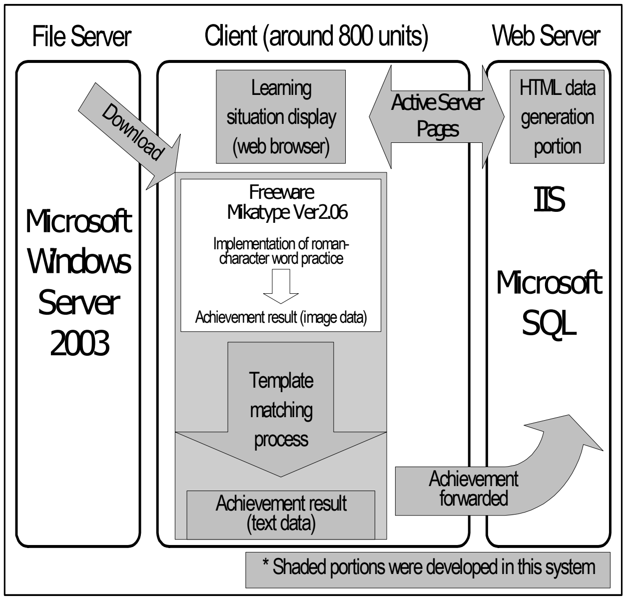

Fig. 2 System structure and process flow

2.4 Capturing learning results for storage in a database

Fig. 3 shows the processing flow chart for capturing learning results. In order to capture the learning results, it is necessary to detect the timing for capturing the Mikatype achievement results screen. As the software we used displays the learning result at the completion stage of the typing test, the mechanism is to capture the screen when the display of learning result changes on the upper right of the Mikatype screen.

When an image change is detected by the agent running on this system, the Mikatype achievement results screen is captured to the clipboard, the data (elapsed time, keystroke count, input speed, errors) are converted from image data to text data through template matching, and then the results data are transferred to the SQL server.

2.5 Display of learning results

A management system built using ASP is the mechanism that automatically transfers the achievement data of learning results extracted from the image data to the SQL server, and it serves also as a mechanism for searching and viewing this data.

There are four display items: the individual learning situation (entire data), individual learning situation (exercise progress situation), total enrollment learning situation, and input speed rank. The input speed rank is displayed sorted in descending input speed. Student ID numbers are displayed in the ranking, enabling each learner to look up where they are situated with respect to the rest of the class.

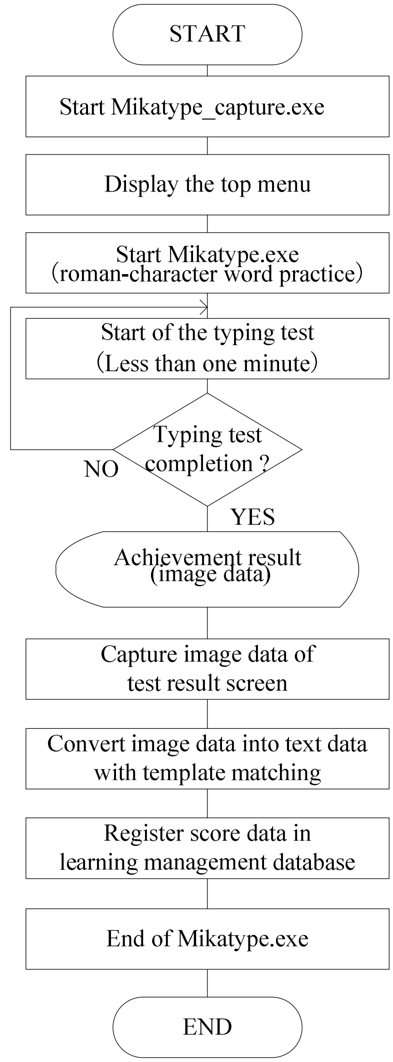

Fig. 3 Processing flow chart

3. Demonstration experiment and evaluation

3.1 Application of the system in actual lessons

At Kinki University, where one of the authors works, this system is operated on over 800 PCs for actual practice and applied to the information literacy course "Practice of Computer III" with around 600 enrolled students (Faculty of Economics).

This subject is targeted at obtaining the MOS PowerPoint 2007 qualification, and, at the start of each lesson, typing practice is carried out using Mikatype for around 10 minutes. Our system reported here is used for practice from the 10^{th} week onwards. There were 723 students enrolled in this subject in the 2010 academic year and among them the following exercise was set up for 15 classes numbering 640 students. Within the 15-week

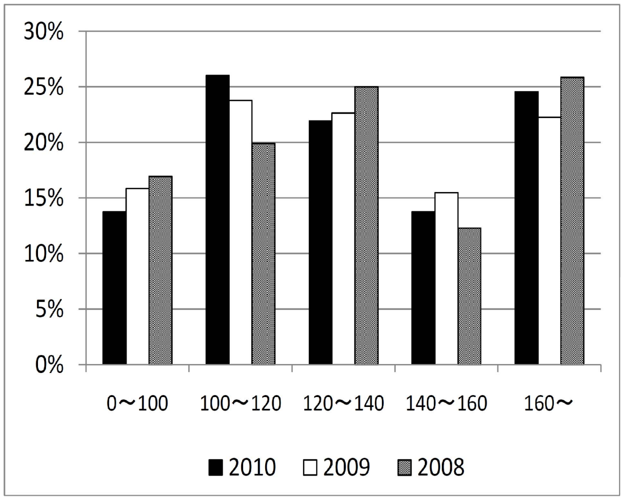

Fig. 4 Score distribution percentages of end-of-term test (typing test)

course, a typing test is held in the 14th week and testing based on the MOS PowerPoint simulated exercise is held in the 15th week.

[Exercise]

With Mikatype's "roman-character word practice," an achievement of entering more than 100 characters per minute is to be registered in the Mikatype learning aid system.

3.2 End-of-term typing test results and considerations

After operating for around five weeks, it was possible to obtain the learning results data of 640 students from the SQL server. A total of 11,735 records was obtained, an average of around 18 per student.

In order to evaluate and certify the "Practice of Computer III" subject unit on trial, an end-of-term typing test was held in the 14th week. The average score for the 2010 academic year, the year in which this system was applied, was 130 characters per minute. Past scores for the years 2009 and 2008, when the system was not applied, were 130 characters per minute and 132 characters per minute, respectively. Fig. 4 shows the score distribution of the three groups as a histogram according to the percentages for each range.

In analyzing the typing test results, when the average score of the 2010 group, for which the system was applied, was compared with average scores for the groups of years 2009 and 2008 when the system was not applied, it was not possible to confirm that the average score increased. In fact, comparison of the groups in terms of distributed values confirmed that the average score was lower for the 2010 group to which the system was applied. However, when the 2010 group was compared with the 2009 and 2008 groups using a histogram, it was possible to confirm that there were fewer students below the 100 characters per minute level in 2010. We conclude that the system raised the achievement level of those at the bottom.

In the last lesson, questionnaires were given to the class (640 students) of year 2010 that used this system. Of these, 604 completed questionnaires were returned. Students who answered "think very much so," or "think so" for "learning desire satisfied" of Question 1 and "typing improved" of Question 2 were respectively 85% and 80%. The implementation of the practice support system is thought to be highly regarded with so many students giving positive views.

Table 1 Relation between end-of-term MOS test and touch-typing

End-of-term MOS test	Typing test (average score)	Typing speed improvement value based on this system (average value)	This system's learning count (average value)	Number of students
95–100	141.4	43.1	22.6	143
90–94	130.3	37.8	19.1	247
85–89	123.6	38.7	17.1	108
80–84	121.5	31.9	16.1	62
0–79	113.8	33.4	11.2	30

3.3 End-of-term MOS test's correlation results and considerations

In the 15th week, the end-of-term MOS test was held. The average scores of the test results for year 2010, year 2009 and year 2008 were respectively 90 points, 86 points and 88 points.

The group of year 2010 with our system applied is a group that learned to use both our system utilizing Mikatype and the learning results automatic collection system used for MOS test. The year 2009 group used only the latter system and the year 2008 group did not use either system. When the average scores of the end-of-term MOS test were compared, the 2010 group that utilized both systems had the highest score of 90 points.

Table 1 gathers together the measurement values related to touch-typing and end-of-term MOS test. It classifies the end-of-term MOS test score percentages by tiers, and for each tier it gives respectively the average values per group for the results of the 14th week typing test, the speed improvement values and the number of

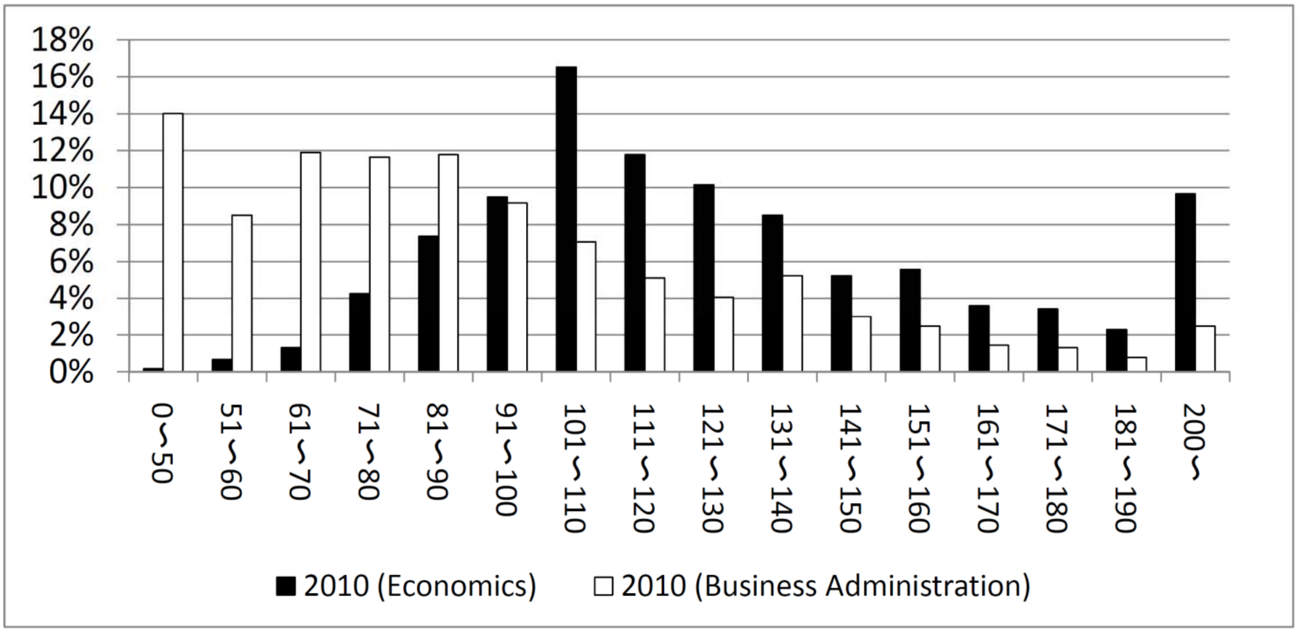

Fig. 5 Mikatype measurement results by faculty

times the system was used. The speed improvement values were derived by deducting the lowest value from the highest value of typing measurement based on the data collected for learning results using our system. This table shows that the group with the good end-of-term MOS test achievement also had a high average value for the typing test as well as a high average value for the number of times the system was used.

In addition, in the questionnaire survey, on the question of whether the use of both this system for typing and the MOS learning aid system mutually stimulated learning, 75% of the students replied "very much think so" or "think so."

In view of these results, it can be said that the implementation of the learning results automatic collection system for touch-typing, in no small way, has a positive effect on the end-of-term MOS test results.

3.4 Comparison with another faculty and effectiveness of the developed system

For this research project, the learning results automatic collection system was only used in the Faculty of Economics. With the cooperation of the Faculty of Business Administration, the Mikatype's "roman-character word practice" measurement was taken in the 14th week, without using the automated result collection system.

In the Faculty of Economics, measurements were taken for 611 students in the 14th week. In the Faculty of Economics, practice was held for approximately 10 minutes at the start of lessons from the 1st week, and with the implementation of this system from the 11th week. By way of contrast, in the Faculty of Business Administration, measurements were taken for 764 students in the 14th week. In the Faculty of Business Administration, Mikatype typing practice was explained in the 1st week and the students were then only instructed to practice in their own time, with no practice during the lesson.

Fig. 5 is a graph showing the measurement results of Mikatype's "roman-character word practice" for the Faculty of Economics and the Faculty of Business Administration. The Faculty of Economics has fewer students achieving less than 100 characters per minute, and the average value is 130. On the other hand, the average value for the Faculty of Business Administration is 90 characters per minute, and it can be seen that there was a substantial number of students achieving less than 100. Based on these results, although practice was held during lessons in the Faculty of Economics, it can be said that the implementation of this system contributed in no small way to the improvement of touch-typing speed.

4. Improvement to the image processing method for automatic collection of learning results

The template matching process used in this demonstration experiment was rebuilt based on the fixed-coordinate template-matching process as reported. For the score results screen in this system, even if the PC system environment differed because of OS differences or the presence of a graphics card, the fonts did not differ, and template matching was possible with fixed coordinates.

However, for the Mikatype software used in this project, depending on the PC system environment, there were occurrences of font shape differences and font plotting, and the coordinate positions of items to extract also differed. In order to be accessible to many students, it was necessary to use the PCs available in the university under various environments. It was necessary to adjust the characters of the template to each PC environment and acquire the coordinate axis of reading positions as well as arrange the set up to reflect these in the program. Consequently, system development took much time.

As such, in order to increase efficiency in development, a new system was built by taking screen capture for the required minimum portions rather than fixed coordinates, searching one type of template prepared in advance in sequence and specifying the number having the smallest residual, which succeeded in bringing down the development cost. Although it was necessary to prepare templates of multiple patterns as there were multiple PC resolutions in the university, this was incorporated into the system by always changing the resolution to SXGA before Mikatype startup through the SetDisplayMode[6] method utilizing DirectX.

In addition, because of this improvement to the image-processing method, the processing times of new and old systems were also comparatively measured. This is the measurement, using the PCs in the university, of the time between acquisition of the image data of achievement results and generation of the text data representing the results. When the processing times were compared, the new system's processing time was substantially reduced by the improved image processing method.

In this way, as a result of an improved image-processing method, a reduction of the time and cost of system development was achieved, and the processing time could be shortened too.

5. Conclusion

As reported, a system was developed to collect automatically the implementation results of learning using electronic text available in the market, and it became possible to understand the progress of each student. As well, teaching staff could better manage the learning process, and the teaching effectiveness was successfully raised to a certain extent.

Through a similar method, reported here, a system was developed and evaluated for managing the learning of each student by automatically collecting the achievement results for implementation situations using a freeware software teaching typing in information literacy education involving many students. Both systems adopted the method of converting image data to text data through template matching after capturing the achievement results screen. This system uses existing application software, and it is necessary to control timing externally for capturing the achievement results screen. This timing requires some actions, and it was confirmed that the achievement results screen could be acquired through the timing of termination of the application software or image change.

Around 640 students used this system and grappled with practicing touch-typing. The project was successful in having each student situation and ranking information automatically presented almost without awareness of this system running in the background.

As long as this system's automatic acquisition of learning results was working, the student users' competitive awareness based on ranking information was greatly stimulated and the effectiveness of being able to learn actively was confirmed. Furthermore, improved achievement in typing and the MOS simulation problem test with the use of this system was confirmed.

Although the further development could not be applied in an actual demonstration experiment, the system was successfully developed at a reduced development cost by tackling the image processing method for the automatic collection of learning results.

In the future, we wish to implement an efficient learning aid system with reduced development cost and without operating cost by applying the learning aid system utilizing the newly developed image processing method in a demonstration experiment.

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